AFAPL-TR-66-132

AIR FORCE AERO PROPULSION LABORATORY EFFORTS UNDER THE RTD PLAN FOR IMPROVED AIRCRAFT TURBINE ENGINE LUBRICANTS

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TECHNICAL REPORT AFAPL-TR-66-132

JANUARY 1967

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AIR FORCE AERO PROPULSION LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report was prepared by the Air Force Aero Propulsion Laboratory. The described efforts were accomplished under Project 3044, "Aerospace Lubrication," Task 304401, "Turbine Engine Lubrication Engineering." The work was administered under the direction of the Fuels, Lubrication, and Hazards Branch, with Mr. Kerry L. Berkey, project engineer; Mr. George A. Beane IV, task engineer; Mr. Leon J. DeBrohun, senior engineer; and 1/Lt. Earl N. Hanel and 1/Lt. James C. Ghiglieri, engineers.

This report covers work conducted from September 1964 to October 1965 and was submitted 25 November 1966.

This technical report has been reviewed and is approved.

Arthur V. Churchill

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ABSTRACT

Some Air Force using commands were concerned as to the adequacy of MIL-L-7808E synthetic lubricants for aircraft turbine engines because of deposit forming characteristics. In addition, the U. S. Navy was investigating a class of heavier ester fluids for turbine use. Its requirements for these oils were listed in Specification MIL-L-23699. In agreement with the Air Force Logistics Command, the Research and Technology Division established a full-scale program to improve USAF gas turbine lubricants. The program, "RTD Plan for Improved Aircraft Turbine Lubricants," was conducted jointly by the Systems Engineering Group and the Air Force Aero Propulsion Laboratory. The program was conducted in three phases: investigation of more stringent MIL-L-7808 requirements, assessment of MIL-L-23699 oil capabilities, and investigation of advanced new materials. This report covers only the efforts of the Air Force Aero Propulsion Laboratory in the program.

From the program, MIL-L-7808E was upgraded to MIL-L-007808F (USAF) by tightening existing requirements and adding new deposit forming and elastomer compatibility test requirements. MIL-L-7808 and MIL-L-23699 oils were compared and found to be comparable from a deposit forming standpoint. The decision was made to retain the MIL-L-7808 oils as the standard USAF aircraft turbine lubricant. Efforts were initiated to develop better oils than either the 23699 or existing 7808 oils.

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SECTION I

INTRODUCTION

The MIL-L-7808 class of synthetic lubricants was initially developed to meet the operational requirements of high performance turbojet engines such as the J-57 and J-71. After a number of years of research and exploratory development, the first MIL-L-7808 specification was issued in 1951. In 1952, initial use for flight was in the F-100 fighter aircraft.

The 7808 oils have provided good service over the years. Occasional problems did arise. The solutions of some of these problems along with normal advancement of the state of the art provided the data for the nine specification revisions and amendments, which have resulted in continuous improvement in this class of fluids.

For the past several years, San Antonio Air Materiel Area (SAAMA) personnel have expressed concern that the 7808E oils were generating extensive deposits in turbine engines. However, they produced no concrete evidence to this effect. During the Spring of 1964, field investigations by Air Force Aero Propulsion Laboratory (AFAPL) personnel found no evidence of excessively dirty engines. As a result, little effort was expended on improving the 7808E oils at that time.

In the meantime, the U. S. Navy was investigating a class of heavier ester fluids for turbine use. It listed the requirements for these oils in Specification MIL-L-23699.[1] The Navy's primary interest in the fluids was their higher gear load-carrying ability for turboprop and turboshaft engines as well as helicopter gear boxes and transmissions. During its investigations, the Navy determined that the 23699 fluids demonstrated cleaner operating capabilities than the 7808D and 7808E fluids which were in general use at the time. During the Spring of 1965, the Navy decided to convert all of its turbine engines to the 23699 oils. At that time, the AFAPL was seriously considering converting USAF turbine engines to this oil also. In fact, by joint agreement between the Air Force Logistics Command (AFLC) and the Research and Technology Division (RTD), the F-105 and F-106 aircraft were changed over to the 23699 oils during this period. However, RTD assumed a cautious attitude concerning an across-the-board use of this oil because of its unknown impact on low-temperature starting requirements and because of its questionable use in equipment other than engines, such as constant speed drives, starters, air turbine motors, etc., which use engine lubricants.

On 17 June 1964, Maj. Gen. W. T. Hudnell, Commander, SAAMA, visited AFAPL and discussed the turbine oil situation with AFAPL and Systems Engineering Group (SEG) personnel.[2] AFLC and RTD agreed to coordinate their efforts to determine if problems did exist. In addition, RTD agreed to initiate a program to investigate the 7808E oils versus the 23699 oils.

On 2 September 1964, Brig. Gen. G. J. McClernon, Director, Maintenance Engineering, Hq AFLC, expressed his concern about turbine lubricants in a letter to Maj. Gen. M. C. Demler, Commander, RTD. As a result, RTD decided to honor the AFLC request for a full-scale program to improve USAF gas turbine lubricants even though no firm data had been presented indicating the existence of problems. During September 1964, RTD outlined and initiated a three-phase program. The phases were:

1. Investigate more stringent MIL-L-7808 requirements. Develop more suitable deposition test limits and better quality control

[1] Pratt and Whitney Aircraft Division, investigating the same class of fluids, refers to them as Type II oils.

[2] AFAPL and SEG are components of RTD.

procedures for acceptance of production batches. Completion date was scheduled for March 1965.

2. Assess MIL-L-23699 oil capabilities. Develop information to determine ultimate usefulness of this oil in USAF engines and other systems. Scheduled completion date was September 1965.

3. Investigate advanced new materials. Develop an oil with 23699 high-temperature and gear load-carrying properties and 7808 viscosity characteristics. Scheduled completion date was September 1965.

During November 1964, Maj. Gen. F. J. Ascani, Deputy Commander, RTD, requested a formal test plan be generated covering the oil program. The "RTD Plan for Improved Turbine Engine Lubricants" which was approved by Col. W. L. Moore, SEG (SEN), on 7 January 1965, is given in Appendix I. The schedule of phases listed in the preceding paragraph was retained.

From 29 December 1964 through 6 January 1965, several incidents occurred at Beale AFB, California, which appeared to substantiate the concern of SAAMA. During this period, five engines installed in B-52G and KC-135 aircraft on ground alert status rejected their oil out the overboard vent line during coast down after short alert exercises. In addition, 12 engines in flight rejected their oil after periods of 10 minutes to 18 hours. The cause was the gross oil degradation deposits which had loosened in the engines and clogged the oil scavenge screens. These, in turn, caused an oil flow and breather pressure unbalance and resulted in the oil rejection.

During the on-site investigations at Beale AFB, abnormal amounts of water were found in approximately 40% of the engine oil systems. It was believed that the water was ingested during a period of high humidity and driving rains just prior to the incident. Full-scale engine tests conducted in the AFAPL were unsuccessful in demonstrating the exact method of water ingestion. During the subsequent investigations by RTD, it was demonstrated that the water loosened the deposits which normally are very tenacious. It must be recognized, however, that the water was merely a triggering mechanism. The basic cause of the problem was the dirty condition of the engines.

The Beale incidents justified the SAAMA concern and gave added impetus to the RTD program already under way. In fact, additional engine testing was scheduled to provide more meaningful data for the RTD program. These tests included two 2000-hour J-57-43 engine tests to compare a 23699 oil with a 7808F oil. The tests are discussed in Section II.

This report covers the AFAPL efforts under the "RTD Plan for Improved Turbine Engine Lubricants." AFAPL was responsible for those work areas in Appendix I which list "Berkey, APF" as the principal engineer.

SECTION II

TECHNICAL EFFORTS

The AFAPL approach to the various tasks of the RTD Plan follows:

1. Task I, upgrade MIL-L-7808 - At one time, 11 different oil formulations were qualified to Specification MIL-L-7808E. The aim in this task was to determine if one or more of these oils appeared superior to the others from a deposit formation standpoint. The qualification data on these oils were reviewed and compared. Additional testing beyond MIL-L-7808E requirements was also conducted.

2. Task II, assessment of MIL-L-23699 oil - The goal was to develop data on 23699 oils in the same tests used for the 7808 oils so that deposit forming characteristics of the two oil classes could be compared directly. The comparison of the requirements for the two specifications is shown in Table XVII.

3. Task III, develop new oil - Initially, the aim was to incite interest in the synthetic lubricant industry towards the development of new fluids which would exhibit 7808 viscosity characteristics and 23699 cleanliness and gear load-carrying capabilities. After the completion of Task I in February 1965, this aim was changed towards the development of new fluids with better cleanliness characteristics and 23699 gear load-carrying ability. The 7808E viscosity characteristics were retained as a requirement.

The AFAPL efforts had to be not only directed to fluid evaluation but required considerable test-method development work to derive new techniques for lubricant evaluation. It was obvious, especially after the Beale incidents, that the test methods available at that time did not adequately define oil capabilities for extended aircraft turbine use. In many cases, specific work was involved in both areas in that candidate fluids would be evaluated in test methods that were under development. In addition, although the RTD Plan lists three separate tasks, AFAPL efforts were conducted concurrently since basically the same test methods were used in each task. Therefore, this section will cover the efforts in each work area rather than follow the three tasks.

In the RTD Plan, the AFAPL assignments were those items that designated "Berkey, APF" as the principal engineer. The remaining items were assigned to SEG (see Appendix I) and will not be covered in this report. The parenthetical information following the listed work areas investigated by AFAPL indicates the task number, the paragraph number, and the subparagraph number of the RTD Plan (Appendix I).

1. Panel Coker (I.2.A, II.1.A, and III.2.A)

The RTD Panel Coker Test is used to determine the tendency of aircraft turbine lubricants to form coke (solid oil decomposition products). The test method consists of splashing a fluid against a heated stainless steel panel for 8 hours under established test conditions. The weight of the coke deposited on the panel at the end of the test is the parameter for measuring coking tendencies.

The RTD Panel Coker is a Modified Model "C" Panel Coker which was used in the early versions of Specification MIL-L-7808. Initially, interest in the Panel Coker waned in favor of the WADC Deposition Test which replaced the coker test in MIL-L-7808D, 9 November 1959. Interest in the Panel Coker was revived during the past several years by Industry who feel a solid decomposition product test is needed. Various modifications to the Model "C" Panel Coker have been made and others are still under investigation. AFAPL became interested in the modified coker through the efforts of the Flight Propulsion Division, General Electric Company, Cincinnati, Ohio. Appendix II contains a resumé of the AFAPL work on modifying the Model "C" Panel Coker which led to the RTD Panel Coker. These modifications are primarily intended to establish a more positive control of test conditions which are

suspected of having an influence on test results. Test conditions are maintained at:

Sump temperature	- 300°F (except for a few tests at 400°F)
Air flow	- 300 cc/min
Air temperature	- 400°F
Panel temperatures	- 625°F, 675°F, and 700°F (an individual run is made at each temperature)
Test time	- 8 hours per run

The initial RTD Panel Coker work during late 1964 and early 1965 was actually performed under contract with Phoenix Chemical Laboratory, Chicago, Illinois. Table I lists the data generated by Phoenix during this time. These data were used to establish the test method and limits used in Specification MIL-L-007808F(USAF), 5 February 1965. This work was performed on cokers which had only the modifications listed in Paragraph 1, Appendix II. The first four oils listed in Table I provided the basis for establishing the specification limits. Oils 6 and 8 subsequently became 7808F oils.

Subsequently, the AFAPL initiated RTD Panel Coker work with another contractor, the University of Dayton (UD). The first discrepancy noted between the two testing laboratories was the UD cokers gave consistently higher coking values than Phoenix. Table II lists comparative data showing three of the four best oils which are listed in Table I. In most cases, the UD test results do not meet the established specification limits which are based on the Phoenix data. These results indicated that reproducibility between the laboratories was not good. Table III lists the UD results on all oils obtained under the RTD program.

Later, several features in the coker design which had drastic effects on test results were investigated. Paragraph 2, Appendix II, lists the modifications which were examined and are still being investigated. Due to the effect these modification studies had on test results, the engineering approach to the test has been changed. At present, the coker design is being screened for areas which need redesign to reduce the effects of these areas. At such time as it is felt that the test method is sufficiently repeatable, then new limits will be established for existing oils and the specification will be modified accordingly. In the meantime, the current specification limits will be retained but will not be considered as cause for rejection of a qualification candidate lubricant.

2. Oxidation - Corrosion (I.2.B, II.1.B, and III.2.B)

Oxidation - corrosion tests are employed in lubrication work to determine oil resistance to oxidation from entrained air and to corrosion of metals in an oxidizing environment. The standard oxidation-corrosion test used in MIL-L-7808 is performed at 347°F and is defined by Test Method 5308 in Federal Test Method Standard No. 791a. Since all the oil formulations listed on the qualified products list for 7808E met the requirements, no significant separations of these formulations were encountered. Test temperatures were elevated to attain separation in an effort to quantitatively compare the formulations. At 385°F, apparent separations were obtained as can be seen under the 7808E formulations listed in Tables IV through XII. These tables list data generated on some MIL-L-23699, MIL-L-7808D, and MIL-L-007808F (USAF) oils, and on formulations introduced under Task III. No significant metal corrosion was noted during any of the testing until the higher test temperatures were attained. Total acid number increase was generally high due to the extreme chemical stressing of the oils in this type of testing.

Two types of tests were used, refluxing and nonrefluxing. The standard 347°F test uses the refluxing technique, that is, a condenser is installed in the exhaust thus condensing the oil vapors and permitting them to run back into the test oil. The nonrefluxing technique allows the vapors to be ejected overboard. No significant advantages of one technique over another could be noted.

The elevated temperature oxidation - corrosion test does not measure the characteristics desired during this program. The

oils with known high coking values do not necessarily appear bad in this testing. For instance, past experience has shown that the two 7808D oils listed in Tables IV through XII have poor coking characteristics. However, they gave very good results in this testing. The 7808F oils which are oils 6 and 8 did not fare so well in the elevated temperature oxidation - corrosion tests but are known to have good coking characteristics. The 23699 oils exhibited good stability in these tests and under coking conditions as well. Elevated temperature oxidation - corrosion testing is not considered to be measuring the parameters of interest in this program. The test conditions apparently do not represent those encountered in service. Other tests, such as the panel coker and the vapor phase coker, will be used to study those parameters.

The standard 347°F oxidation - corrosion test with the present limits will be retained in MIL-L-7808.

3. Bearing Rigs (I.2.C, II.1.C, and III.2.C)

Full-scale bearing tests are used to study lubricant deposit forming characteristics in the presence of a full-scale antifriction bearing operating at normal turbine rotating speeds and temperature conditions. Two different bearing rigs were used in this program. Both rigs consist of a 100-mm test bearing mounted in a steel cylindrical housing known as the Erdco Bearing Head. The rigs differ in their physical dimensions, in the oil systems outside the test head, and in the oil heating method. One configuration, the Coordinating Research Council (CRC) Standard Rig, uses a rectangular oil tank, internal heater, and external oil pumps. The other rig, known as the Southwest Research Institute (SwRI) Modified Rig, employs a round oil tank, external oil heater, and oil pumps suspended in the oil tank. The SwRI Modified Rig was developed for high-temperature bearing testing.

Test conditions for the two rigs were:

	Standard	SwRI Modified
Oil-in temperature, °F	300	340
Tank oil temperature, °F	340	350
Bearing outer race temperature, °F	500	500
Bearing speed, RPM	10,000	10,000
Oil flow, cc/min.	600	600
Duration, hours	100	48

Additional information concerning the Standard Test can be obtained in Method No. 3410, Type I, of Federal Test Method Standard No. 791a. To date, no formal test procedures for the SwRI Modified Test have been prepared.

The eleven 7808E and 7808F oil formulations were screened in each rig. Table XIII lists the generated data. A general trend can be noted whereby the two tests rate the oils in the same descending order. However, there are enough reversals to forego the use of either rig for specification purposes (note Oils 16, 19, and 25). Some significance is possible, however, since four oils (1, 6, 8, and 11) did perform sufficiently well in both tests to be considered as acceptable in the evaluation.

In addition, five MIL-L-23699 oils were tested for informational purposes. The SwRI Modified Test obtained a much greater spread than the standard configuration. No significance can be attached to this difference at this time.

Development efforts are continuing on the bearing tests to obtain more repeatable and reproducible results as well as correlation between the two rigs.

4. Elastomers (I.2.D, II.1.D, and III.2.D)

MIL-L-7808 through the E revision required the oils to be compatible with Buna-N type elastomers. The "H" stock was used as a standard for this class of elastomers and only the rubber swell characteristics were measured. In recent years, improved elastomers have been developed and are in use in USAF turbine engines and allied equipment. These are primarily fluorocarbon (Viton A) and fluorosilicone materials. The Viton materials have better high-temperature properties than the fluorosilicones but do not

exhibit as good low-temperature properties. Therefore, both types are used today depending on the application.

A program was initiated to upgrade the elastomer compatibility requirements for 7808 oils. The data generated on all test oils during the RTD program are listed in Table XIV. Upon the request of Industry and the Air Force Materials Laboratory, other elastomeric materials were investigated, and their physical properties were determined as well. When 7808F was written, the fluorocarbon elastomer requirements were included in the specification (See Table XVII). However, subsequent testing has indicated these limits are not too meaningful since results at 400°F for the fluorocarbon materials and at 350°F for the fluorosilicone materials tend to be high, especially for tensile strength and hardness. With such a severe test, the results can vary somewhat as noted in Table XIV.

Current efforts are aimed at establishing more realistic test conditions to avoid the existing marginal test conditions, marginal for both the oils and the elastomers. It appears that reducing the test temperatures will accomplish the desired results. For the fluorocarbon elastomers, a test temperature of 347°F (175°C) is presently under investigation. In addition, the AFAPL Lubrication Group is working closely with the SAE G-4 Committee on oil-elastomer testing. This cooperative group is attempting to establish a suitable elastomer standard material for the fluorosilicone class. The "F" stock appears to be a suitable standard for the fluorocarbon class of elastomers.

5. Vapor Phase Coker (I.2.E, II.1.E, and III.2.E)

One area of concern which has not been covered by the standard lubricant tests in the past is vapor phase coking in the upper areas of the bearing compartment and compartment walls and breather lines of turbine engines. The Beale AFB problem was caused by the flaking off of coke deposited in these areas. During engine operation, the oil in these areas was believed to exist in two forms: as vapors and as a finely divided mist generated by high speed bearings. Therefore, work was initiated to develop a test for determining the coking characteristics of lubricants in the vapor and mist phases or in combinations of the two phases.

The test, known as the RTD Vapor Phase Coker, is a bench-scale apparatus using a 1000-ml three-neck flask as the sump, a heating mantle for the flask, a 6-inch heated section of 1/2-inch stainless steel tubing as a stack, a 6-inch unheated section, and temperature controllers for the flask and the stack. The test section is insulated on the lower half and uninsulated on the upper half to maintain a relatively large temperature differential within the 6-inch length of the test section. To aid in maintaining this temperature differential, a constant bleed air ring continuously cools the uninsulated portion of the test section. The test temperature is taken at the exit from the heated section. Test conditions are:

Test temperature, °F	700
Oil temperature, °F	350
Airflow, cc/min.	1990
Oil sample, ml	750
Test duration, hours	17

Initially, a glass test section was used to permit visual inspection of the deposits. However, it was determined that a more desirable test section is one of stainless steel, the same as is used in breather lines. Present experimental work is devoted to the use of a disposable test section made of 0.003-inch stainless steel shim stock which is mechanically restrained in a manner so that it can be opened for visual inspection of the deposits at the conclusion of a test run.

The majority of the data generated to date has been for the purpose of investigating different variables using a 7808E oil, Oil 25, as a control. Some of these data are listed in Table XV. A review of the data indicates that the test is not too repeatable yet and, based on existing knowledge generated in other tests, may not even be giving the proper ratings. Note the wide variance between the two 7808F oils which should have comparable

ratings in this type of test. The 7808D oil reading which is low, should be higher since this class of fluids is known to be more susceptible to coke formation than the 7808F oils.

Efforts are continuing to develop a suitable test method from a rating and a repeatability standpoint. Another aim, also, is to reduce the test duration to 12 hours so a test can be completed and the equipment cleaned and made ready for the next test within a two-shift time span.

6. Infrared (I.2.F).

When an oil formulation is qualified to Specification MIL-L-7808, the complete formulation listing all ingredients, their proportions, and sources are listed. No deviation from this specific formulation including sources of the ingredients is permitted without requalification. This requirement is intended to assure that each batch of oil manufactured to this formulation is as nearly identical as possible to that originally qualified. A problem exists in that no techniques have been developed for use with synthetic lubricants whereby batch constituents can be chemically analyzed. AFAPL has embarked on a program to develop such techniques. One such technique which was studied was infrared (IR) analysis. The 7808F version requires IR analysis of the qualification sample and each production batch.

After study of many IR traces of turbine oils, the conclusion has been reached that the IR technique is not sensitive enough for this purpose. One area of interest in the analysis is the identity and level of contaminants. Unfortunately, the classes of contaminants of interest usually fall in the same light bands as the original materials of formulation. Thus the contaminants are masked out. Therefore, further work on the infrared technique is not planned.

Future studies in this area will be devoted to other techniques such as gas chromotography, differential thermal analysis, ultraviolet emission, etc.

7. Seal Deposition (I.2.G, II.1.F, and III.2.F)

In the past, difficulties have been encountered with oil degradation products collecting on dynamic seal parts of turbine engines and interfering with the proper operation of the seals. The RTD Seal Rig was developed under contract to study oil deposits on carbon seals. This rig consists of a full-scale face riding carbon seal (J-93 No. 2 Seal) installed in a test head. Rotating power is provided by an external drive system. The head is provided with a circulating oil system and means to heat the air on the air side of the test seal. Air leakage through the seal is measured. When this leakage exceeds a predetermined rate, usually 5 cubic feet per minute (cfm), the test is terminated. Deposit levels are determined for information purposes.

During the RTD oil program, the following test conditions were maintained:

Speed, RPM	7000
Seal air pressure, psi	30
Seal air temperature, °F	900
Oil flow, gpm	0.35
Bulk oil temperature, °F	350
Number of oil jets	2

Table XVI lists the data generated during the program period. The best oils in these tests were the Task III oils which are 3-centistoke fluids under investigation under Task III as possible replacements for the 7808F oils. It is interesting to note that the Task III oils performed better than the 23699 oils which, however, were very good. One of the 7808F oils gave a good performance while the other one was marginal. The 7808E oils ranged from unsatisfactory to good. The only 7808D oil tested also gave good results. These results are not too conclusive since they are based on single data points. Work is continuing in which duplicate runs will be made.

The test appears to be a valuable tool for oil studies. The extent of its usefulness will

be determined by future correlative work between the rig, engine tests, and experience.

8. Full-Scale Engine Tests (I.2.H, II.1.G, and III.2.G)

Full-scale engine tests are required to qualify turbine engine synthetic lubricants. Most of the other required testing is primarily intended to screen candidate fluids to determine if they warrant an engine test. One of the goals of lubricant test method development is to attain a level of confidence such that expensive and time-consuming full-scale engine testing will not be required.

The Pratt and Whitney J-57-29 engine has been the MIL-L-7808 qualification test engine for a number of years. The MIL-E-5009 engine equalification test cycles are used in the 100-hour oil test. This combination of engines and test cycles subjects the oil to a very severe test environment. Post-test inspection consists of rating the engine condition primarily with respect to deposits in the oil wetted areas. Abnormal wear or other deterioration is also noted. A rating then is determined for each oil in comparison with past performance of the other oils on the qualified products list.

No engine tests were performed under Task I of the RTD program since all the 7808E oils qualified to that time had been subjected to an engine test as part of their qualification requirements. The engine test records on these oils were reviewed to determine if any demonstrated cleaner engine performance. It was determined that two of the 7808E oil formulations were somewhat superior to the remainder of the oils. Specification MIL-L-007808F (USAF) was written around these two oils. One of the remaining oils was found to be somewhat dirtier than all the rest in certain areas. This oil had been serviced to Beale AFB prior to the Beale incidents and is believed to have contributed to the dirty condition of those engines.

Under Task II, two MIL-L-7808 qualification 100-hour J-57-29 engine tests were conducted on 23699 oils. The cleanliness ratings were comparable to those of the two 7808F oils. One of the 23699 oils removed excessive amounts of lead from the bearing cages. The other 23699 oil did not attack the lead plating. Normally, this lead removal feature is grounds for not qualifying a 7808 oil. However, for the purposes of this investigation, no significance was attached to this phenomenon. Due to rather extensive experiences in military and commercial aircraft turbines, the fear of the effects of lead removal is declining rapidly. No detrimental effects have been reported in service.

As a result of the added incentive generated by the Beale incidents, two 2000-hour J-57-43 engine tests were conducted to compare 7808F and 23699 oils. One engine operated with a 7808F oil while the other used a 23699 oil. Again, comparable deposit levels were obtained between the two oils.

No candidate fluids were developed prior to the close of the RTD program; thus no full-scale engine testing was accomplished under Task III.

Test reports covering the individual engine tests mentioned above may be obtained from the Air Force Aero Propulsion Laboratory.

9. Foaming

Although foaming is not listed as a work area in the RTD Plan for Improved Turbine Engine Lubricants (see Appendix I), foaming investigations were conducted during the program and will be reported here.

Upon release of MIL-L-007808F (USAF) and its associated QPL-007808-1, the various equipment manufacturers obtained supplies of the qualified oils for testing in their equipment and test methods. Allison Division of General Motors Corporation, among other things, tested the oils in the Allison Foam and Aeration Rig, which circulates the test oil through orifices, pumps, lines, tanks, etc., under simulated sea-level and altitude aerating conditions. One of the qualified 7808F formulations exhibited excessive foaming tendencies in this test. The manufacturer made a slight additive change in the formulation which was then requalified after exhibiting low aeration tendencies in the Allison Rig.

Considerable efforts were expended by AFAPL in attempting to simulate Allison Rig results in simple glassware equipment such as that used in Federal Test Method Standard 791a, Test Method No. 2211, which defines the standard foam test for 7808 oils. Air flows were adjusted in the 2211 test. A Waring Blender was attempted to introduce mechanical oil churning as well as air flow. Initial results were not too promising.

In the meantime, the use of the high foaming formulation was restricted from use in the T-56, engine by T.O. 42B-1-620, 11 June 1965, which was released by MAAMA. When the Royal Canadian Air Force (RCAF) received a copy of the T.O., it contacted the AFAPL for guidance since it had been using the faulty oil in some of its C-130 aircraft almost exclusively for 6 months. No problems with fluctuating or reduced oil pressures were experienced and no indication of foaming was evident. No RCAF orders were issued restricting the use of the oil, but several commands did restrict its use to engines other than the T-56. The Canadians have since switched their procurements to the modified formulation.

Since the completion of the RTD oil program, AFAPL has continued efforts on the development of a suitable foam and aeration test.

TABLE I

PHOENIX TEST RESULTS ON 7808E OILS
USING RTD PANEL COKER

Oil Code	Panel Temperature (°F)	Coke Formed (mg)	Viscosity Change (% at 100°F)	Neutralization Number Change (mg KOH/gm oil)	Amount Evaporated (ml)
6[a]	625	17	0.6	0.33	115
	675	49	4.7	3.24	100
	700	242	6.3	6.08	200
11	625	72	- 0.3	0.04	75
	675	56	-10.0	0.19	90
	700	240	-14.7	0.91	150
10	625	45	- 3.1	0.26	100
	675	138	-10.5	0.34	100
	700	261	-11.4	0.53	100
8[a]	625	34	- 0.4	0.15	110
	675	175	-14.3	0.46	100
	700	258	-15.0	0.55	
1	625	92	1.9	0.22	80
	675	204	- 4.5	0.46	125
	700	243	6.9	0.31	100
16	625	186	6.5	1.30	95
	675	237	17.7	8.19	125
	700	125	11.8	5.02	200
19	675	94	- 8.7	0.10	100
	700	589	-10.0	0.35	225
2	625	61	2.1	0.33	95
	675	185	4.1	0.80	50
	700	818	4.7	2.10	175
4	625	227	- 3.9	0.57	100
	675	500	- 9.8	1.19	75
	700	701	-15.0	1.40	150
7	625	139	- 0.9	0.27	125
	675	686	- 8.4	0.84	125
	700	757	- 7.8	0.70	175
25	675	495	7.8	6.52	200
	700	1086	7.4	7.51	250

[a]This oil later was classified as a 7808F oil.

TABLE II

COMPARISON OF PHOENIX AND UNIVERSITY OF DAYTON PANEL COKER TEST RESULTS

Oil Code	Coke Formed at 675°F (mg)		Coke Formed at 700°F (mg)	
	Phoenix	UD	Phoenix	UD
6	49	104	242	360
8	175		258	282
11	56	233	240	792

TABLE III

UNIVERSITY OF DAYTON PANEL COKER TEST RESULTS

Oil Class	Oil Code	Coke Formed at 625°F (mg)	Coke Formed at 675°F (mg)	Coke Formed at 700°F (mg)
MIL-L-7808E	5	12(4)[a]		
	11	12(2)	233(15)	792(7)
MIL-L-7808F	6		104(9)	360(6)
	8			282
	32	37	216	387
	36		140(2)	380(2)
	40		234	471
	41		186	272
	42		302	461
	43		255	358
	47	15(2)	213(3)	417(4)
MIL-L-23699	20	57(9)	133(10)	107(14)
	23	16	62	99(2)
	28	74(2)	108(2)	111(2)
	37	96	137	156(3)
	38	85	74	130
Task III	26			588(2)
	27	26(2)	117(3)	134(2)
	29			75
	30	63(3)	89(3)	126(4)
	31	33(2)	67(3)	58
	33			76
	34	33(4)	86(3)	154(3)
	35	100	155	154
	39			289
	44	155	384	606(3)
	45	177	265	562(2)
	46	60	172	320(3)
	48	29	69	410
	49	280	499	583
	54			397
	55			184

[a]The numbers in parentheses indicate the number of individual runs. Results are averages.

TABLE IV

OXIDATION - CORROSION TEST RESULTS, PERCENT OF VISCOSITY INCREASE AT 100°F

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data						From Monsanto Research Corporation Data: Nonrefluxing Exhaust			
			Refluxing Exhaust -	Nonrefluxing Exhaust								
			385°F[a]	350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22	3.8		13	13	114	16	23	5.1	60	46(2)[b]	
	24					5	28(2)	G[c]		180	G	
7808E	1	1.8		140	145	390	482	G	-1.9	96	141	151
	2	1.8		10	15	25	32(2)	G(2)	5.4(2)	46	44	18
	4	4.7		19	44	103(2)	153(2)	G	-2.6	218	51(2)	198
	7	1.3	79	17	43	107(2)	241	G	-0.7	2	137	224
	10	-1.4			66	144	327	G	-8.2	71	106	282
	11	-1.5	110		57	70	G(2)	G	-14.8(2)	73	197(2)	123
	16	2.7			29	20	24	38(2)	5.1	18	98	287
	19	2.3	153			170	320	G		20		101
	25	1.7			20	27	31	G		71	368(2)	190
	56				27	53						
	57				16	23						
	58				17							
	56-57-58[d]				23							
7808F	6	1.0	71(2)	26	48	72	86(2)	387(2)	0.0	28	343	523
	8	-0.9	54(2)	23	67	122(3)	G(2)	G	-11.8	33	198(2)	164
	32	1.0	271			319						
	36	-2.6	452			577						
	40		129			148						
	41		48			59						
	42	1.4	174			76						
	6-8		84(2)			96						
23699	20		19		15	19	22	28		20	43	
	23		23		17	24	26	183		17	28	
	28		10(2)			11						
	37	8.5	16			16						
	38	5.0	26			26	26					
	20-23		19									
	20-28		14									
	23-28		19			18						
	20-23-28		15									
Task III	26						8					
	27		10			10	12(2)	16				
	29	9.8	106			109	127					
	30	0.7	630			532	2402					
	31		51			50	60					
	33		15			16	18					
	34		32			31	38					
	35	0.8	8			8(2)						
	45		148			1141						
	46		31			34						
	48		226			1768						
	49		6559			12650						
	50		58			59						

[a] Test oil temperature.

[b] The numbers in parentheses indicate the number of individual runs. Results are averages.

[c] Gelled; no determinations made.

[d] Mixtures of equal portions.

TABLE V

OXIDATION - CORROSION TEST RESULTS, NEUTRALIZATION NUMBER, mg KOH/gm OIL

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data: Refluxing Exhaust - 385°F[a]	From Southwest Research Institute Data: Nonrefluxing Exhaust - 350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	From Monsanto Research Corporation Data: Nonrefluxing Exhaust 375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				0.96	1.27	1.36	2.24	1.42	18.5	19.9(2)[b]	
	24					1.57	12.96(2)	49.6		24.8	43.6	
7808E	1	0.61		0.49	1.08	1.67	1.68	G[c]	1.86	9.4	7.0	10.6
	2	0.52		0.42	0.73	1.10	1.65(2)	G(2)	1.91(2)	22.0	28.7	17.6
	4	1.38		0.83	0.85	1.28(2)	1.69(2)	G	7.9	12.0	12.3(2)	12.2
	7	0.73	1.14	0.62	1.23	1.70(2)	2.22	G	1.80	8.0	15.2	8.0
	10	0.79			1.03	1.54	3.17	G	3.6	5.7	8.6	22.1
	11	0.60	2.19		0.99	13.96	G(2)	G	7.2(2)	12.0	8.3(2)	8.9
	16				0.55	0.50	0.63	0.72(2)	0.72	8.7	18.1	21.8
	19	0.64	1.17			1.14	6.73	G		9.9	9.2	6.5
	25	1.36			1.10	1.69	3.19	G		21.1	26.2(2)	20.0
	56				0.83	1.19						
	57				0.43	0.49						
	58				0.98							
	56-57-58[d]				0.84							
7808F	6	0.58	1.10(2)	0.52	0.86	1.21	1.41(2)	10.06(2)	1.68	12.5	16.6	7.0
	8	0.62	7.90(2)	0.58	0.90	8.75(3)	33.6(2)	G	10.5	7.5	11.9(2)	17.0
	32		1.83			2.01						
	36		30.7			28.9						
	40		1.68			1.85						
	41		10.49			1.29						
	42	0.76	26.4			1.25						
	6-8		1.35(2)			1.47						
23699	20		0.31		0.31	0.38	0.36	0.47		0.68	4.9	
	23		0.04		0.07	0.10	0.09	5.73		0.42	2.2	
	28		0.15(2)			0.15						
	37		0.45			0.45						
	38	0.14	0.59			0.54						
	20-23		0.15									
	20-28		0.29									
	23-28		0.11			0.08						
	20-23-28		0.17									
Task III	26						0.26					
	27		0.46			0.41	0.48(2)	0.54				
	29	0.27	0.47			0.41	0.46					
	30	0.20	29.2			26.2	21.5	21.5				
	31		0.06			0.09	0.07					
	33		0.45			0.50	0.48					
	34		0.31			0.30	0.31					
	35	6.5	0.21			0.21(2)						
	45		0.86			0.84						
	46		0.62			0.64						
	48		2.27			3.46						
	49		18.75			21.8						
	50		0.65			0.65						

[a]Test oil temperature.

[b]The numbers in parentheses indicate the number of individual runs. Results are averages

[c]Gelled; no determinations made.

[d]Mixtures of equal portions.

TABLE VI

OXIDATION - CORROSION TEST RESULTS, PERCENT OF OIL LOSS BY WEIGHT

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data: Refluxing Exhaust - 385°F[a]	Nonrefluxing Exhaust - 350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	From Monsanto Research Corporation Data: Nonrefluxing Exhaust 375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				23	31	34	43	0.4	5.0	6.7(2)[b]	
	24					28	37(2)	55		5.9	6.7	
7808E	1			34	52	60	65	71	1.3	5.9	9.7	20.8
	2			23	39	50	57(2)	67(2)	0.8(2)	5.2	8.0	4.9
	4			28	43	57(2)	61(2)	68	2.2	5.8	9.6(2)	9.8
	7		54	27	42	57(2)	62	64	0.9	4.4	7.5	5.9
	10				48	57	63	68	1.2	5.3	6.9	10.1
	11		57		44	57	66(2)	69	1.7(2)	4.9	7.6(2)	7.4
	16				27	35	39	48(2)	0.2	2.4	5.5	6.3
	19		55			56	62	72		4.5	8.0	6.3
	25				28	36	43	58		4.5	6.9(2)	6.0
	56				41	55						
	57				26	35						
	58				27							
	56-57-58[c]				33							
7808F	6		43(2)	23	34	42	47(2)	53(2)	0.5	2.9	6.4	5.8
	8	28	54(2)	28	42	57(3)	68(2)	69	4.9	4.1	7.9(2)	7.6
	32		60			64						
	36		58			60						
	40		54			59						
	41		52			45						
	42		54			45						
	6-8		50(2)			50						
23699	20		16		10	15	17	20		3.1	3.1	
	23		18		14	19	21	30		17.0	2.1	
	28		12(2)			21						
	37		11			11						
	38		10			9						
	20-23		17									
	20-28		13									
	23-28		15			13						
	20-23-28		15									
Task III	26						26					
	27		24			23	25(2)	32				
	29		52			54	58					
	30		44			45	50					
	31		55			57	60					
	33		9			9	10					
	34		27			27	32					
	35		15			16(2)						
	45		50			52						
	46		42			45						
	48		58			63						
	49		46			47						
	50		44			43						

[a]Test oil temperature.

[b]The numbers in parentheses indicate the number of individual runs. Results are averages.

[c]Mixtures of equal portions.

TABLE VII

OXIDATION - CORROSION TEST RESULTS, ALUMINUM WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data: Refluxing Exhaust - 385°F[a]	From Southwest Research Institute Data: Nonrefluxing Exhaust - 350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	From Monsanto Research Corporation Data: Nonrefluxing Exhaust 375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				0.12	0.26	0.26	0.51	0.02	0.10	0.26(2)[b]	
	24					0.14	0.27(2)	0.41		0.10	0.15	
7808E	1			0.02	-0.04	0.02	-0.06	0.04	-0.03	0.03	0.14	0.03
	2			0.12	0.26	0.22	0.28(2)	0.56(2)	-0.04(2)	0.06	0.12	0.19
	4	0.0		0.10	0.12	0.06(2)	0.06(2)	0.20	0.0	0.02	0.04(2)	0.05
	7	0.02	0.04	0.08	0.02	0.03(2)	0.0	0.0	0.01	0.0	0.05(2)	
	10				0.0	0.0	0.0	0.06	0.05	3.51	-0.01	0.03
	11	0.0	0.0		0.0	0.0	0.02(2)	0.14	-0.01(2)	-0.02	-0.02(2)	0.07
	16				-0.02	0.02	0.0	0.08(2)	0.0	0.02	0.02	0.02
	19		0.0			0.02	0.04	0.0		-0.03	0.01	
	25				0.0	0.0	0.02	0.0		-0.03	0.02	
	56				0.04	0.0						
	57				0.04	-0.06						
	58				0.0							
	56-57-58[c]				0.0							
7808F	6	0.0	0.05(2)	0.06	-0.02	0.02	0.0(2)	0.02(2)	-0.01	-0.06	-0.04	0.04
	8	0.0	0.0(2)	0.04	0.06	0.02(3)	0.0(2)	0.0	0.0	-0.02	0.02(2)	0.0
	32		-0.04			-0.12						
	36		-0.10			-0.18						
	40		0.0			0.0						
	41		0.0			0.0						
	42		0.0			0.0						
	6-8		0.02(2)			-0.06						
23699	20		-0.04		-0.02	-0.06	0.06	0.14		-0.06	-0.05	
	23		0.04		0.04	0.0	-0.02	0.14		0.02	0.02	
	28		0.01(2)			0.06						
	37		0.0			0.0						
	38		0.0			0.0						
	20-23		0.02									
	20-28		0.0									
	23-28		-0.02			0.06						
	20-23-28		0.02									
Task III	26						-0.02					
	27		0.02			0.0	0.03(2)	-0.02				
	29		0.06			0.0	0.02					
	30		0.0			0.0	0.02					
	31		0.0			-0.02	0.0					
	33		-0.02			0.0	0.0					
	34		-0.02			-0.02	0.0					
	35		0.0			0.01(2)						
	45		0.0			0.0						
	46		0.0			0.0						
	48		0.02			0.02						
	49		-0.02			0.0						
	50		0.0			0.0						

[a]Test oil temperature.

[b]The numbers in parentheses indicate the number of individual runs. Results are averages.

[c]Mixtures of equal portions.

TABLE VIII

OXIDATION-CORROSION TEST RESULTS, TITANIUM WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust -	From Southwest Research Institute Data							From Monsanto Research Corporation Data: Nonrefluxing Exhaust			
			Refluxing Exhaust -	Nonrefluxing Exhaust -									
		347°F[a]	385°F[a]	350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]		375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				0.08	0.36	0.26	0.51					
	24					0.14	0.27(2)[b]	0.30					
7808E	1			-0.06	-0.04	0.04	0.0	-0.02					
	2			0.14	0.24	0.22	0.23(2)	0.29(2)					
	4			0.0	0.02	0.04(2)	-0.02(2)	0.0					
	7		0.0	0.02	-0.06	0.02(2)	-0.02	0.02					
	10				0.0	0.02	-0.02	0.67					
	11		0.0		0.04	0.02	0.01(2)	0.0					
	16				-0.02	0.04	0.04	0.08(2)					
	19		0.02			0.0	0.02	0.30					
	25				0.04	0.0	-0.02	-0.22					
	56				0.0	-0.02							
	57				-0.02	-0.02							
	58				0.04								
	56-57-58[c]				0.0								
7808F	6		0.06(2)	0.02	-0.04	0.02	-0.02(2)	0.04(2)					
	8		0.01(2)	-0.02	-0.14	-0.01(3)	0.02(2)	0.04					
	32		-0.08			-0.12							
	36		-0.08			-0.12							
	40		0.0			0.02							
	41		0.0			0.0							
	42		-0.02			0.02							
	6-8		0.0(2)			-0.02							
23699	20		0.0		-0.06	0.0	0.04	-0.06					
	23		0.0		-0.02	0.02	-0.02	-0.18					
	28		0.02(2)			-0.06							
	37		0.04			0.02							
	38		0.04			0.0							
	20-23		0.0										
	20-28		0.0										
	23-28		0.0			-0.04							
	20-23-28		0.06										
Task III	26						0.0						
	27		-0.04			-0.02	0.04(2)	-0.02					
	29		0.0			0.0	0.0						
	30		-0.02			-0.06	0.0						
	31		-0.06			-0.04	0.0						
	33		-0.06			-0.08	-0.02						
	34		-0.06			-0.06	-0.02						
	35		0.0			0.02(2)							
	45		0.02			0.04							
	46		0.0			0.02							
	48		0.02			-0.02							
	49		0.02			-0.02							
	50		0.02			0.0							

[a]Test oil temperature.

[b]The numbers in parentheses indicate the number of individual runs. Results are averages.

[c]Mixtures of equal portions.

TABLE IX

OXIDATION - CORROSION TEST RESULTS, SILVER WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust -	From Southwest Research Institute Data						From Monsanto Research Corporation Data: Nonrefluxing Exhaust			
			Refluxing Exhaust -	Nonrefluxing Exhaust -								
		347°F [a]	385°F [a]	350°F [a]	375°F [a]	385°F [a]	390°F [a]	400°F [a]	375°F [a]	400°F [a]	425°F [a]	430°F [a]
7808D	22				0.12	0.24	0.12	0.37	-0.01	0.10	0.16(2)[b]	
	24					0.16	0.27(2)	0.53		0.08	0.17	
7808E	1			0.0	0.06	0.06	0.02	0.10	-0.39	-0.05	0.05	1.58
	2			0.04	0.26	0.24	0.16(2)	0.27(2)	0.04(2)	0.02	0.12	0.88
	4	0.01		0.18	0.37	0.13(2)	0.03(2)	0.28	-0.1[illegible]	0.0	0.03(2)	-0.04
	7	0.03	0.02	0.0	-0.02	0.05(2)	0.02	0.0	-0.01	0.0	-0.02(2)	
	10				0.0	-0.02	0.02	0.02	-0.02	0.0	0.0	0.01
	11	0.0	-0.10		0.0	-0.02	0.03(2)	0.04	-0.03(2)	-0.39	0.03(2)	0.02
	16				0.0	-0.04	0.02	0.01(2)	0.0	-0.02	-0.02	0.0[illegible]
	19		-0.02			0.0	0.06	0.02		0.02	0.04	
	25				-0.02	0.0	0.02	-0.02		-0.02	0.04	
	56				0.08	0.0						
	57				0.02	-0.02						
	58				0.0							
	56-57-58[c]				0.0							
7808F	6	0.01	0.01(2)	0.0	0.08	0.0	0.01(2)	-0.02(2)	-0.05	-0.08	-0.03	0.14
	8	0.01	0.0 (2)	-0.04	0.0	0.04(3)	0.02(2)	-0.04	-0.04	-0.05	0.0(2)	0.06
	32		-0.02			-0.04						
	36		-0.04			-0.08						
	40		-0.02			0.0						
	41		-0.02			-0.04						
	42		-0.06			-0.04						
	6-8		0.0(2)			-0.02						
23699	20		0.02		-0.04	0.06	-0.04	0.0		-0.05	-0.03	
	23		0.0		-0.02	0.04	0.0	0.0		-0.03	-0.25	
	28		0.03(2)			0.04						
	37		0.0			0.0						
	38		-0.02			0.0						
	20-23		0.02									
	20-28		0.0									
	23-28		0.04			0.04						
	20-23-28		-0.02									
Task III	26						0.0					
	27		-0.06			-0.06	-0.02(2)	-0.02				
	29		-0.02			-0.06	-0.04					
	30		0.0			0.0	-0.04					
	31		0.04			-0.02	0.0					
	33		0.06			0.0	-0.02					
	34		0.06			-0.06	-0.04					
	35		0.0			0.01(2)						
	45		0.0			0.0						
	46		0.0			0.0						
	48		0.02			0.0						
	49		-0.18			-0.12						
	50		0.0			0.0						

[a] Test oil temperature.

[b] The numbers in parentheses indicate the number of individual runs. Results are averages.

[c] Mixtures of equal portions.

TABLE X

OXIDATION - CORROSION TEST RESULTS, STEEL WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data: Refluxing Exhaust - 385°F[a]	From Southwest Research Institute Data: Nonrefluxing Exhaust - 350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	From Monsanto Research Corporation Data: Nonrefluxing Exhaust - 375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				0.16	0.28	0 10	0.24	0.05	0.12	0.20(2)[c]	
	24					0.12	0.21(2)	-0.04		0.11	0.94	
7808E	1			0.02	0.20	0.08	0.0	0.02	-0.02	0.02	-0.01	0.07
	2			0.26	0.36	0.28	0.19(2)	0.48(2)	0.05(2)	0.16	-1.38	0.31
	4	0.0		0.06	0.12	0.50(2)	0.0(2)	0.0	0.02	0.05	0.48(2)	-0.02
	7	0.02	0.0	0.06	-0.04	0.06(2)	0.04	0.02	-0.02	0.02	-0.54(2)	
	10				-0.02	0.0	-0.08	-0.08	0.00	0.0	-0.01	0.0
	11	0.0	0.02		0.0	0.04	-0.04(2)	0.06	0.02(2)	0.05	0.02(2)	-0.04
	16				0.0	-0.04	-0.12	0.07(2)	0.0	0.04	0.05	-0.05
	19		0.0			-0.02	-0.10	0.06		0.01	0.07	
	25				0.04	0.0	-0.02	0.02		0.05	0.02	
	56				0.0	0.06						
	57				0.06	0.02						
	58				0.0							
	56-57-58[c]				0.04							
7808F	6	0.0	0.03(2)	0.06	0.08	0.02	0.01(2)	0.03(2)	-0.02	-0.02	0.05	0.01
	8	0.0	0.01(2)	0.04	-0.02	0.01(3)	0.03(2)	0.0	-0.01	-0.03	0.02	0.04
	32		-0.02			-0.02						
	36		0.02			0.02						
	40		0.0			0.0						
	41		0.0			0.0						
	42		0.0			0.0						
	6-8		0.0(2)			0.02						
23699	20		-0.04		0.02	0.04	-0.02	0.30		-0.02	0.07	
	23		0.12		0.04	-0.02	-0.10	0.02		0.04	0.02	
	28		0.01(2)			0.06						
	37		0.02			0.0						
	38		0.0			0.0						
	20-23		0.06									
	20-28		0.0									
	23-28		0.0			-0.02						
	20-23-28		0.06									
Task III	26						-0.02					
	27		0.0			-0.02	0.04(2)	-0.02				
	29		0.0			-0.04	0.04					
	30		0.0			0.0	0.04					
	31		0.0			0.0	0.02					
	33		0.02			-0.02	0.04					
	34		0.0			-0.02	0.04					
	35		0.02			0.01(2)						
	45		0.0			0.0						
	46		-0.02			0.0						
	48		0.02			0.04						
	49		0.06			0.08						
	50		0.02			0.0						

[a] Test oil temperature.

[b] The numbers in parentheses indicate the number of individual runs. Results are averages.

[c] Mixtures of equal portions.

TABLE XI

OXIDATION - CORROSION TEST RESULTS, COPPER WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust - 347°F[a]	From Southwest Research Institute Data: Refluxing Exhaust - 385°F[a]	From Southwest Research Institute Data: Nonrefluxing Exhaust - 350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	From Monsanto Research Corporation Data: Nonrefluxing Exhaust 375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				-0.10	-0.16	-0.14	0.12	-0.23	-0.93	-1.16(2)[b]	
	24					0.18	0.22(2)	0.14		-0.96	-0.86	
7808E	1			0.02	0.0	-0.08	-0.26	-7.6	-0.26	-8.85	-4.48	-2.88
	2			0.14	0.20	0.22	0.17(2)	0.05(2)	-0.12(2)	-0.35	-1.60	-3.49
	4	0.04		0.16	0.30	0.26(2)	0.22(2)	0.34	-0.90	-6.80	-3.62(2)	-3.67
	7	0.09	-0.04	0.0	0.08	-0.03(2)	-0.08	-0.34	-0.10	-0.60	0.29(2)	-0.48
	10				-0.06	-0.16	-0.16	-11.5	-0.25	-15.63	-4.33	-1.41
	11	0.0	-0.59		-0.06	-0.16	-1.12(2)	-4.3	-1.66(2)	-5.83	-2.85(2)	-3.20
	16				-0.20	-0.62	-0.43	-0.41(2)	-0.43	-0.41	-0.75	-0.84
	19		-0.04			-0.02	0.0	0.04		-8.19	-4.61	-4.50
	25				-0.06	-0.10	-0.26	-1.40		-0.93	-3.19	-4.00
	56				0.02	0.0						
	57				-0.30	-0.16						
	58				-0.06							
	56-57-58[c]				-0.06							
7808F	6	0.03	-0.07(2)	-0.08	-0.14	-0.18	-0.21(2)	-0.20(2)	-0.40	-3.44	-5.85	-10.05
	8	0.0	-0.16(2)	0.0	0.18	-0.16(3)	-2.58(2)	-3.94	-1.91	-10.44	-6.50(2)	-1.97
	32		-0.12			-0.10						
	36		-0.04			-0.10						
	40		-0.08			-0.12						
	41		-0.12			-0.18						
	42		-0.27			-0.16						
	6-8		-0.17(2)			-0.16						
23699	20		-0.06		0.0	-0.10	-0.08	-1.54		-0.08	-0.07	
	23		-0.39		-0.47	-0.65	-0.67	-1.28		-1.14	-1.78	
	28		-0.06(2)			-0.06						
	37		-0.06			-0.04						
	38		0.0			0.0						
	20-23		0.10									
	20-28		0.0									
	23-28		-0.84			-0.73						
	20-23-28		0.08									
Task III	26						-0.26					
	27		-0.06			-0.06	-0.08(2)	-0.12				
	29		-0.35			-0.28	-0.39					
	30		-3.73			-4.62	-10.49					
	31		-0.41			-0.41	-0.45					
	33		-0.32			-0.26	-0.28					
	34		-0.81			-0.79	-0.87					
	35		-0.02			-0.10(2)						
	45		-0.04			-0.02						
	46		-0.08			-0.06						
	48		0.0			0.0						
	49		-0.40			-0.18						
	50		0.02			0.04						

[a] Test oil temperature.

[b] The numbers in parentheses indicate the number of individual runs. Results are averages.

[c] Mixtures of equal portions.

TABLE XII

OXIDATION - CORROSION TEST RESULTS, MAGNESIUM WEIGHT CHANGE, mg

Oil Class	Oil Code	From Qualification Data: Refluxing Exhaust -	From Southwest Research Institute Data: Refluxing Exhaust -	From Southwest Research Institute Data: Nonrefluxing Exhaust -					From Monsanto Research Corporation Data: Nonrefluxing Exhaust			
		347°F[a]	385°F[a]	350°F[a]	375°F[a]	385°F[a]	390°F[a]	400°F[a]	375°F[a]	400°F[a]	425°F[a]	430°F[a]
7808D	22				0.20	0.30	0.24	0.40	-0.02	-0.09	-0.81(2)[b]	
	24					0.18	0.24(2)	0.16		0.0	0.81	
7808E	1			-0.06	0.16	0.02	0.0	-0.34	-0.01	-0.73	-51.60	D[c]
	2			0.0	0.45	0.26	0.21(2)	0.53(2)	-0.03(2)	0.0	-0.22	- 5.36
	4	0.0		0.16	0.34	0.12(2)	0.08(2)	0.20	-0.32	-0.43	D (2)	-11.02
	7	0.01	0.04	0.0	0.06	0.01(2)	0.04	0.06	0.0	-0.36	-8.24(2)	-49.00
	10				0.10	0.04	0.0	0.14	0.02	-0.19	-12.71	- 6.59
	11	0.0	0.04		0.18	0.08	0.06	-0.11(2)	-0.01(2)	-0.06	-38.70(2)	-36.18
	16				0.0	-0.12	-0.26	-0.08(2)	0.0	-0.05	-0.07	0.03
	19		0.02			0.08	-0.02	-0.45		-0.07	-2.32	D
	25				-0.02	-0.02	0.0	0.02		-0.04	0.06	-15.00
	56				0.04	-0.04						
	57				-0.08	-0.06						
	58				0.0							
	56-57-58[d]				0.08							
7808F	6	0.01	0.06(2)	0.10	0.0	0.04	0.01(2)	-0.12(2)	0.02	-0.05	-2.95	-31.78
	8	0.0	0.04(2)	0.0	0.04	0.03(3)	0.03(2)	-0.26	0.0	-0.15	-2.78(2)	- 3.75
	32		0.02			0.10						
	36		0.0			-0.16						
	40		0.10			0.0						
	41		0.08			0.0						
	42		-0.73			-0.04						
	6-8		0.0(2)			-0.06						
23699	20		0.0		0.0	0.02	-0.06	0.0		-0.02	7.30	
	23		0.08		0.0	0.0	0.0	-0.02				
	28		0.0(2)			-0.06						
	37		0.0			0.06						
	38		0.02			0.04						
	20-23		0.0									
	20-28		0.0									
	23-28		-0.02			-0.06						
	20-23-28		0.02									
Task III	26						0.0					
	27		-0.14			0.08	-0.15(2)	-0.22				
	29		0.06			0.20	0.0					
	30		0.06			-0.08	0.0					
	31		0.0			0.10	-0.04					
	33		-0.02			0.14	-0.04					
	34		0.0			0.16	-0.12					
	35		0.0			0.0(2)						
	45		0.02			0.0						
	46		0.0			0.04						
	48		0.18			0.20						
	49		0.08			0.14						
	50		0.04			0.12						

[a] Test oil temperature.

[b] The numbers in parentheses indicate the number of individual runs. Results are averages.

[c] Disintegrated.

[d] Mixtures of equal portions.

TABLE XIII

BEARING TEST RESULTS

Oil Class	Oil Code	CRC Standard Method				SwRI Modified Method			
		Deposit Rating	Viscosity Increase (% at 100°F)	Final Neutralization Number (mg KOH/gm Oil)	Oil Loss (ml/hr)	Deposit Rating	Viscosity Increase (% at 100°F)	Final Neutralization Number (mg KOH/gm Oil)	Oil Loss (ml/hr)
7808E	1	100	-5.7	5.9	12.3	81	-1.6	2.3	56
	2	123	8.3	5.4	7.5	133	8.8	4.7	40
	4	121	-10.1	11.6	9.1	113	-6.3	13.2	60
	7	150	-4.7	14.4	13.7	103	-1.2	5.8	45
	10	120	-11.9	11.1	13.4	105	-8.0	3.0	49
	11	95	-14.8	5.5	8.5	81	-10.5	8.2	58
	16	74	5.8	6.2	9.5	108	9.4	5.7	40
	19	89	-18.2	5.7	8.7	133(3)[a]	-11.3(3)	2.7(3)	55(3)
	25	85	-5.3	7.0	7.0	104	1.4	14.4	49
7808F	6	61	2.6	3.9	8.1	88(2)	3.4(2)	2.4(2)	36(2)
	8	97	-16.4	11.6	15.7	90	-11.0	2.7	50
23699	20	49	10.9	0.1	6.1	32	8.0	0.2	15
	23	64	7.4	0.1	4.4	121	10.2	0.3	20
	28	41	2.8	0.0	5.8	96	6.4	0.2	17
	37	65	7.7	0.2	11.1	24	7.4	0.2	10
	38					20	8.9	0.3	11

[a] The numbers in parentheses indicate the number of individual runs. Results are averages.

TABLE XIV

ELASTOMER TEST RESULTS

Oil Class	"H" Stock Swell (%)	"F" Stock 400°F, 72 Hours				Viton A 400°F, 72 Hours				Fluorosilicone 350°F, 70 Hours			
		Swell (%)	Tensile Change (%)	Elongation Change (%)	Hardness Change (Shore No.)	Swell (%)	Tensile Change (%)	Elongation Change (%)	Hardness Change (Shore No.)	Swell (%)	Tensile Change (%)	Elongation Change (%)	Hardness Change (Shore No.)
7808D													
22	25	24	-47	3	-15					5	-40	-3	-7
7808E													
1	26					18	-39	-2	-12	8	-42	-6	-8
2	29	17	-33	0	-12	16	-43	0	-15	10	-69	-17	-18
4	27	19	-55	-22	-16	18	-55	-14	-17	8	-82	-44	-20
7	27					19	-39	-23	-10	8	-4	-9	-5
10	30					19	-60	-27	-12				
11	31	19	-59	-26	-10	19	-59	-26	-10	11	-37	0	-6
16	27	18	-72	-43	-9	14	-62	-15	-10	D[a]	D	D	D
19	25	19	-29	0	-10	19	-29	0	-10	11	-37	0	-6
25	26	13	-19	0	-18	11	-39	0	-10	5	-82	-50	-18
7808F													
6	30	10	-35	-41	-12	16	-38	-35	-15	10	-69	-17	-18
8	25	27	-49	-10	-17	20	-50	-16	-12	13	-48	0	-15
32	26	20	-60	-26	-15	19	-57	0	-19	9	-80	-31	-22
42	26	21	-44	-2	-13					10	-41	-18	-9
23699													
20		20	-20	-3	-9	25	-37	0	-14	7	-30	-12	-4
23		30	-39	-2	-13	33	-38	0	-19	5	-61	-18	-6
28		22	-23	-25	-14	25	-32	-9	-16	9	-19	0	-7

[a] Dissolved Rubber

TABLE XV

VAPOR PHASE COKER RESULTS

Oil Class	Oil Code	Deposits (mg)
7808D	22	150.8
7808E	25	112.4
	25	141.0
	25	148.3
	25	155.7
	25	157.9
7808F	41	83.4
	42	246.7
23699	20	126.7

TABLE XVI

RTD SEAL RIG TEST RESULTS

Oil Class	Oil Code	Run Life (Hours)	Deposit Rating No	Viscosity Increase (% at 100°F)	Neutralization No. (mg KOH gm Oil)	Oil-Out Temperature[a] (°F)	Seal Leakage[a] (SCFM)	Oil consumption[a] (lbs/hr)	Seal Wear[a] (microinches/hr)	Failed Seal
7808D	22	76	190	3.7	1.5	384	1.95	0.14	2	secondary
7808E	2	26	173	2.4	0.6	385	.95	0.21	...	secondary
	19	61	150	Nil	1.0	384	2.26	0.11	5	secondary and face
	25	41	134	1.0	1.1	380	2.00	0.11	...	secondary
	25	40	186	Nil	1.2	387	1.34	0.09	Nil	secondary
7808F	6	41	129	11.0	0.5	385	2.33	0.15	...	secondary
	8	89	165	Nil	1.3	384	1.92	0.11	7	secondary and face
23699	20	126	143	10.4	0.5	387	0.85	0.08	...	face
	20	125	134	9.0	0.5	387	1.57	0.09	...	face
	23	97	154	14.4	0.5	384	2.63	0.10	62	secondary and face
Task III	45	162	170	54.0	0.87	386	0.80	0.13	16	secondary
	46	130	135	11.4	....	394	0.95	0.11	19	secondary

[a] Average conditions and results.

TABLE XVII

COMPARISON OF MIL-L-7808 AND MIL-L-23699 REQUIREMENTS

Requirements	7808E	7808F	23699
1. Ortho isomer in TCP, % max	1	1	1
2. Viscosity, cs			
at 210°F	3.0 min.	3.0 min	5.00 to 5.50
at 100°F, min	11.0	11.0	25.0
at -40°F, max			13,000
at -65°F, max	13,000	13,000	
3. Viscosity stability at -40°F 72 hrs, % change max			±6
4. Viscosity stability at -65°F			
3 hrs, % change max	±6.0	±6.0	
72 hrs, cs max	17,000	17,000	
5. Flash point, °F min	400	400	450
6. Pour point, °F max	-75	-75	-65
7. Total acid number, mgKOH/gm oil max	0.30	0.30	0.50
8. Lead corrosion, mg/in^2 max	6	6	6.0
9. Storage stability, mg/in^2 max			
2 days	25	25	25
7 days	150	150	150
10. Extended storage stability	pass	pass	pass
11. Low-temperature storage stability			pass
12. Evaporation, % loss max	35	35	10
13. Trace sediment, ml/200 ml oil max	0.005	0.005	0.005
14. Color, ASTM max	3		
15. Foaming, ml max/total collapse time in seconds max			
Sequence 1	25/180	25/180	25/60
Sequence 2	25/180	25/180	25/60
Sequence 3	25/180	25/180	25/60
16. Deposition Number, max	3.5	3.5	
17. Shear stability, % max			4
18. Load carrying ability, % relative rating, min			
2 determinations	76	76	96
4 determinations	72	72	91
6 determinations	70	70	88
8 determinations	68	68	

TABLE XVII (Cont'd)

Requirements	7808E	7808E	23699
19. Elastomer compatibility			
H Stock swell, %	12 to 35	12 to 35	10 to 25
F Stock			
Swell at 400°F, %		2 to 35	10 to 25
Tensile change, % max		75	
Elongation change, % max		50	
Hardness change, Shore Number max.		25	
20. RTD Panel Coker, mg max			
625°F		50	
675°F		175	
700°F		300	
21. Thermal stability			
Viscosity at 100°F, % change max			5.0
Total acid number increase, mg KOH/gm oil max			2.0
22. Corrosion - oxidation at 347°F			
Metal weight change, gm/cm^2 max			
Cu	±0.4	±0.4	±0.4
Al	±0.2	±0.2	±0.2
Ag	±0.2	±0.2	±0.2
St	±0.2	±0.2	±0.2
Mg	±0.2	±0.2	±0.2
Viscosity at 100°F, % change	-5 to 15	-5 to 15	-5 to 15
Total acid number increase, mgKOH/gm oil max	2.0	2.0	2.0
23. Corrosion - oxidation at 400°F			
Metal weight change, gm/cm^2 max			
Cu			±0.4
Al			±0.2
Ag			±0.2
St			±0.2
Mg			±0.2
Viscosity at 100°F, % change			-5 to 25
Total acid number increase, mgKOH/gm oil max			3.0
Sludge content, mg/100 ml oil max			50
24. Corrosion - oxidation at 425°F			
Metal weight change, gm/cm^2			
Cu			report
Al			report
Ag			report
St			report
Mg			report
Viscosity at 100°F, % change			report
Total acid number increase, mgKOH/gm oil			report
25. Silver - copper corrosion, mg/in^2 max			
Ag	3.0	3.0	
Cu	3.0	3.0	
26. Compatibility	pass	pass	pass

TABLE XVII (Cont'd)

Requirements	7808E	7808E	23699
27. Deposition compatibility		pass	
28. Bearing test			
Demerit rating, max			80
Filter deposits, gm max			3
Consumption, ml max			2,000
Viscosity at 100°F, % change			-5 to 25
Total acid number increase, mgKOH/gm oil max			2
29. 100-hour engine endurance test	pass	pass	
30. Turboprop engine test			pass
31. Helicopter transmission test			pass
32. Workmanship	pass	pass	

SECTION III

DISCUSSION OF PROGRAM RESULTS

1. TASK I

Of the 11 MIL-L-7808E oil formulations evaluated, two were found to exhibit better overall deposit forming characteristics than the remainder. This conclusion was based primarily on the review of the J-57 engine qualification test results. Laboratory test results indicated these two formulations were among the better ones. Several other formulations also appeared good in laboratory test results but were poorer in the engine tests.

MIL-L-007808F (USAF) was written using the two best 7808E oils as a baseline. This specification was released on 5 February 1965. Three new requirements were added at this time: the use of F stock and physical properties to the elastomer test, the RTD Panel Coker, and deposition compatibility using the RTD Panel Coker.

In March 1965, all procurement of MIL-L-7808 oils was converted to 7808F oils.

2. TASK II

As noted in the tables, the MIL-L-23699 oils exhibited better cleanliness characteristics than the MIL-L-7808D and 7808E oils. After the selection of the two 7808F oils under Task I, the 23699 oils still appeared better in laboratory testing. However, a comparison of the results of engine test conducted by AFAPL showed the 23699 oils and the 7808F oils to be equivalent from a deposit forming standpoint. Two types of test were analyzed: the MIL-L-7808 qualification J-57-29 engine 100-hour test and the special J-57-43 engine 2000-hour test.

The main difference of concern to the Air Force between the 23699 and 7808F oils was their low temperature properties. The 23699 oils, being heavier in viscosity, are listed as -40°F oils while 7808 fluids are categorized as -65°F oils. Separate studies by the Systems Engineering Group indicated that, in some USAF applications, unassisted low-temperature starting capabilities would be limited to as high as -20°F. Therefore, the limiting low-temperature properties of the 23699 oils dictated the RTD decision that the USAF would retain 7808 oils as the standard aircraft turbine lubricant. This decision was announced on 6 October 1965, which is considered as the closeout date of the "RTD Plan for Improved Turbine Engine Lubricants."

3. TASK III

Industry was apprised of the requirements for the new oil (see II.1.C) primarily through personal briefings with technical representatives of the firms which are involved in the turbine synthetic lubricant field.

Due to a lack of sufficient time, Industry was unable to develop suitable candidate fluids under Task III prior to the closeout date for the RTD program. Shortly after this date, oils began to appear as serious candidates for an improved turbine lubricant. This follow-on effort became known as the "Head and Shoulders" program and will be covered in subsequent AFAPL and contractor reports. A few preliminary candidate fluids were screened. The data for these fluids are listed in the tables under Task III.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

Based on the test methods available to AFAPL, the MIL-L-007808F(USAF) oils are considered equivalent to the MIL-L-23699 oils with respect to deposit forming characteristics.

The discrepancies between Laboratory test results and full-scale engine test results require attention. Current laboratory tests are not considered definitive enough in the area of deposit formation. Efforts should be conducted to improve test capabilities in oxidation-corrosion, vapor phase coking, liquid phase coking (panel cokers), and engine test simulation (full-scale bearing compartment rigs including bearings, seals, rotating shafts, hot seal air, etc.).

In addition, the full-scale engine test should be investigated to determine the suitability of the J-57-29 engine to adequately define oil capabilities for all engines and allied equipment. Engine test repeatability and reproducibility also is questionable and warrants investigation.

The aims of Task III, that is, the improvement of aircraft turbine lubricants, should not be confined to some program period but should be pursued aggressively and continuously. It is anticipated that the AFAPL "Head and Shoulders" program will result in the next generation of MIL-L-7808 oils.

APPENDIX I

RTD PLAN FOR IMPROVED TURBINE ENGINE LUBRICANTS

GENERAL 7 January 1965

The objective of this plan is to integrate those efforts necessary to assess and resolve current and future field service problems attributed to turbine engine lubricants. This plan, encompassing three major task areas, will provide the data necessary to make key decisions regarding the acceptability of proposed turbine engine oils and their compatibility with using equipments. The three task areas of this plan are:

Task I	Upgrade MIL-L-7808
Task II	Assessment of MIL-L-23699 Oil
Task III	Develop New Oil

In the course of Task I efforts, an initial exhibit for upgraded MIL-L-7808 oils will be issued in March 1965. The capabilities of MIL-L-23699 oil will be evaluated by September 1965 under Task II efforts. An initial exhibit for a new turbine engine lubricant will be available by September 1965 during the course of Task III efforts.

PROGRAM MANAGEMENT

The plan has been developed and published by direction of Major General F. J. Ascani (Attachment No. 1). As will be noted, the plan recognizes the joint responsibility of the Directorate of Propulsion and Power Subsystems Engineering (SEJ) within the Systems Engineering Group and the Technical Support Division (APF) within the Air Force Aero Propulsion Laboratory and assigns task item responsibilities to individuals of these organizations.

Because of the many organizations, systems, equipments, and functions affected by the oil program, Colonel W. L. Moore, Jr., will be responsible for coordinating all program activity and will act as the focal point for establishing task items, procedures, policies, and individual contacts not already arranged for in the plan.

This program is of vital interest to the Air Force Logistics Command and is being supported to a considerable extent by them. The Accessories, Equipment, and Propulsion Branch (MCMTE) of the Hq AFLC Maintenance Materiel Division will be kept informed of all major program activity and progress. SEJ is charged with this responsibility as well as serving as the office of record for all program activity.

PROGRAM SUPPORT

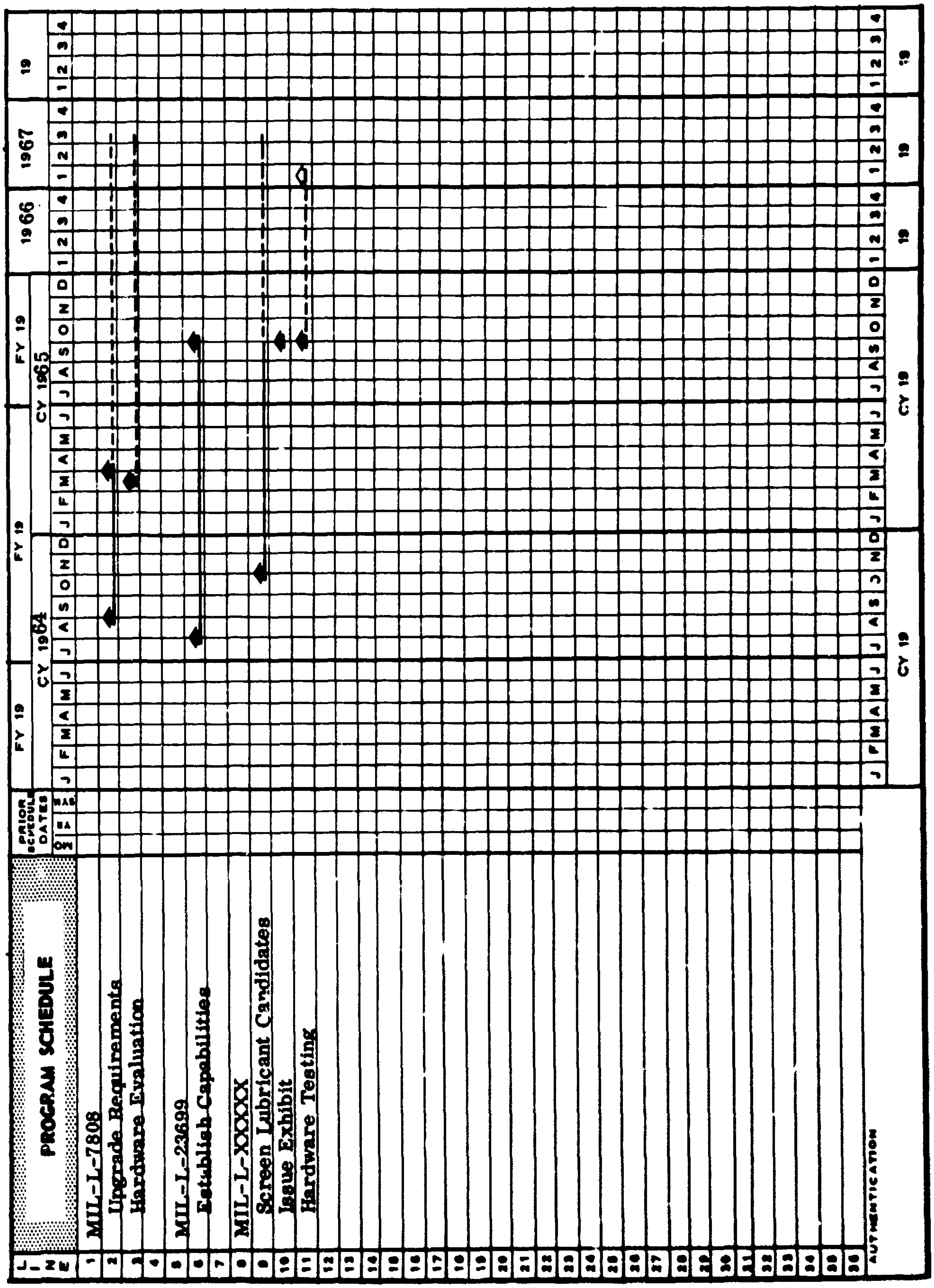
This plan will be implemented within existing project activities and normal organizational functional responsibilities. Increased resources required, if any, will be requested by standard procedures to support these normal functions.

Full use will be made of AFSC/AFLC system and equipment management agencies to obtain the necessary equipment and facility support.

FOR THE COMMANDER

(S)

WALTER L. MOORE, JR.
Colonel, USAF
Deputy for Systems Engineering
Systems Engineering Group


PROGRAM SCHEDULE
MIL-L-7808
Upgrade Requirements
Hardware Evaluation
MIL-L-23699
Establish Capabilities
MIL-L-XXXXX
Screen Lubricant Candidates
Issue Exhibit
Hardware Testing
PRIOR SCHEDULE DATES
CY 1964
CY 1965
1966
1967
AUTHENTICATION

TASK I - UPGRADE MIL-L-7808

1. AFLC, operating commands, and commercial airlines are being queried as to field problems experienced with the use of MIL-L-7808 oils. Information received from the airlines and operating commands will be evaluated in conjunction with AFLC hardware tear-down reports to define specific problem areas which may be resolved by the use of improved lubricants.

A. AFLC - AFLC has presented photos of engine tear-downs to RTD. Only a small number indicated problems with MIL-L-7808. AFLC was asked to provide data on usage rates of parts in conjunction with oil field experience.

Principal Engineer - Maloney, SEJ

Associate Engineer - Berkey, APF

B. Operating Commands - Contact with TAC and ADC is under way. F-105 and F-106 bases were visited and oil usage experience was requested. To date, there is no factual data available on MIL-L-7808 problems. Discussions with TAC, ADC, and other commands is continuing.

Principal Engineer - Reed, SEJ

Associate Engineer - Berkey, APF

C. Commercial Airlines - Contacts with airlines (Delta, Eastern, United, TWA, Pan American, and American) have been made. In general the airlines have considered or are changing oils. The change appears to be largely for economic reasons, although a few new commercial engines operate at oil temperatures that apparently require the newer oil.

Commercial airline experience is increasing rapidly at this time and continued contact is to be achieved. A commercial experience review team will be formed with AFLC and RTD memberships to visit key commercial operators and prepare a comprehensive oil usage report.

Principal Engineer - Reed, SEJ

Associate Engineer - Berkey, APF

D. Navy - The Navy has been contacted to obtain its experience with MIL-L-7808 and provide its reasons for changing to MIL-L-23699 oils.

Principal Engineer - Reed, SEJ

Associate Engineer - Berkey, APF

2. Existing and proposed specification tests will be investigated to determine their suitability for use in the upgraded MIL-L-7808. In addition, the currently qualified MIL-L-7808E oils will be screened in these tests to catalog their capabilities so that the better oils may be selected for retention on QPL-7808. These better oils will, in turn, be used to establish reasonable limits for the adopted tests for use in the upgraded specification. The following tests will be investigated at the temperatures indicated.

A. Panel Coker: A General Electric modification of the Model C panel coker to better control air temperature and air availability to the oil has been made. This test which checks coking characteristics of oils will be conducted at panel temperatures of 625, 675, and 700°F.

B. Oxidation - Corrosion: A standard MIL-L-7808 test performed at 347°F oil temperature will also be run at 375°F. This test determines oil oxidative stability and some corrosive properties.

C. ERDCO Bearing Rig: Using the CRC configuration, Type I tests with 300°F oil-in and 500°F bearing outer race temperatures will be performed. This test measures the lubricity, oxidative stability, and deposit forming characteristics of an oil.

D. Elastomers: MIL-R-25897 (fluorocarbon) and MIL-R-25988 (fluorosilicone) tests will be screened for their suitability as oil-elastomer tests.

E. Vapor Phase Coker: The test measures the coking characteristics of oil mist phase to predict breather line and sump wall deposition problems. Surface temperatures up to 800°F will be investigated.

F. Infrared: IR techniques will be used in an attempt to fingerprint qualification samples in order that production lots may be checked for composition against their respective qualification samples.

G. Seal Deposition: A new test method recently developed for oils will be performed up to 350°F oil and 900°F seal air temperatures to determine oil coking and sludging characteristics in the presence of large dynamic seals.

H. Full-Scale Engine Tests: Qualification tests, as defined in MIL-L-7808E, will be conducted at an oil-in temperature of 300°F on a J-57 engine.

Principal Engineer - Berkey, APF

Associate Engineer - Gandee, SEJ

3. Engine, engine accessory, and helicopter transmission manufacturers are being surveyed for their experience with MIL-L-7808 oils and for suggested changes to the specification tests.

A. Engines: Major engine manufacturers have been contacted and meetings planned to discuss oils. Each manufacturer will present data regarding the use of MIL-L-7808 oil at the meeting and subsequently provide a written summary of its oil experience.

Principal Engineer - Maloney, SEJ

Associate Engineer - Berkey, APF

B. Engine Accessory (Starters, APU's, Coolers, etc.): Hardware manufacturers have been contacted concerning their experience with the oil. Same procedure as for engines will be followed. AiResearch has presented data on starters. Meetings are being planned with other manufacturers but no firm date at this time.

Principal Engineer - Miller, SEJ

Associate Engineer - Berkey, APF

C. Constant Speed Drive: Two major manufacturers have been contacted - General Electric and Sundstrand. Data are available on MIL-L-7808 deficiencies.

Principal Engineer - Wasserman, SEJ

Associate Engineer - Berkey, APF

D. Helicopter Transmissions: All airframe manufacturers were contacted concerning their experience on oils. Letters were sent out in September 1964, but no formal reply to date. However, Sikorsky was visited and oils discussed. Inputs for limitation of certain specification requirements were obtained from Sikorsky. Tests will be conducted and reported by Sikorsky.

Principal Engineer - Hanson, SEJ

Associate Engineer - Berkey, APF

4. Industry shall be requested to evaluate and report experience on the use of upgraded MIL-L-7808 oils in its equipment.

Principal Engineer - Maloney

Associate Engineer - Berkey, APF

5. The requirements for the upgraded MIL-L-7808 oil will be issued as an exhibit and coordinated as Specification MIL-L-7808.

Principal Engineer - Berkey, APF

Associate Engineer - Farrington, SEJ

6. Candidate oils shall be tested for qualification to the upgraded specification requirements.

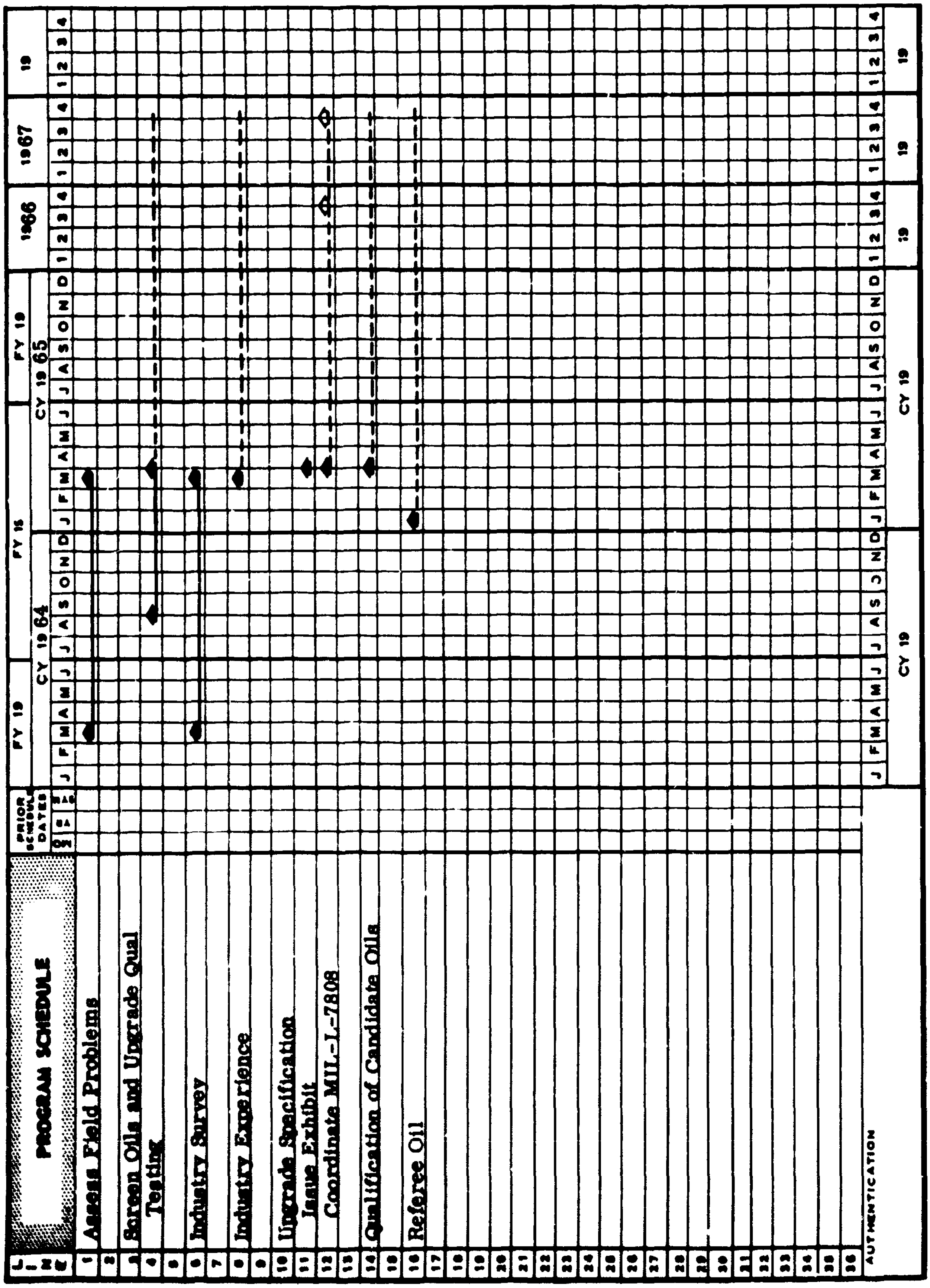
Principal Engineer - Berkey, APF

Associate Engineer - Gandee, SEJ

7. RTD will attempt to define the possibility of establishing a referee oil for use in qualification of hardware. Should the establishment of a referee oil be feasible, such effort will be applied to any new type of oil to be introducted into Air Force use.

Principal Engineers - Berkey, APF

- Wright, SEJ


PROGRAM SCHEDULE
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FY 19
CY 19 64
FY 19
CY 19 65
FY 19
1966
1967
19
Assess Field Problems
Screen Oils and Upgrade Qual
Testing
Industry Survey
Industry Experience
Upgrade Specification
Issue Exhibit
Coordinate MIL-L-7808
Qualification of Candidate Oils
Referee Oil
AUTHENTICATION
CY 19
CY 19
19
19
19

TASK II - ASSESSMENT OF MIL-L-23699 OIL

1. MIL-L-23699 qualified oils will be subjected to a number of standard and proposed oil tests to determine their capabilities as compared to MIL-L-7808 oils. The following tests will be investigated at the temperatures indicated.

A. Panel Coker: A General Electric modification of the Model C panel coker to better control air temperature and air availability to the oil has been made. This test which checks coking characteristics of oils will be conducted at panel temperatures of 625, 675, 725, and 775°F.

B. Oxidation-Corrosion: A standard MIL-L-7808 test performed at 347°F oil temperature will also be run at temperatures of 375, 400, and 425°F. This test determines oil oxidative stability and some corrosive properties.

C. ERDCO Bearing Rig: Type I tests (300°F oil and 500°F bearing outer race temperatures) and higher temperature tests (up to 550°F and 600°F bearing outer race temperatures) will be performed. This test measures the lubricity, oxidative stability, and deposit forming characteristics of an oil.

D. Elastomers: MIL-R-25897 (fluorocarbon) and MIL-R-25988 (fluorosilicone) tests will be used to check oil-elastomer compatibility at temperatures up to 400°F and 350°F, respectively.

E. Vapor Phase Coker: The test measures the coking characteristics of oils in the vapor and oil mist phase to predict breather line and sump wall deposition problems. Surface temperatures up to 1000°F will be investigated.

F. Seal Deposition: A new test method recently developed for oils will be performed up to 400°F oil and 1100°F seal air temperatures to determine oil coking and sludging characteristics in the presence of large dynamic seals.

G. Full-Scale Engine Tests: Qualification tests, as defined in MIL-L-7808E, will be conducted at an oil-in temperature of 300°F on a J-57 engine.

H. Navy: The Navy has been requested to furnish data on all testing accomplished to establish and qualify MIL-L-23699 oils.

Principal Engineer - Berkey, APF

Associate Engineer - Gandee, SEJ

2. Interrupted oil flow studies will be conducted to determine the effects of starting engines with extremely viscous oil at low temperatures on life, reliability, and maintainability especially with respect to bearings.

These studies will be performed as

A. Full-scale bearing tests.

B. Full-scale engine testing, fully instrumented to detect incipient failures due to interrupted flow.

Principal Engineers - Maloney, SEJ

- Berkey, APF

3. A weapon system evaluation of MIL-L-23699 oil will be conducted to assess its operational capability.

A. Low-temperature starting tests will be conducted on a C-141, F-105, and F-106 in the APGC climatic hangar to establish starting limitations.

Principal Engineers - Miller, SEJ

- Cassidy, SEJ

Associate Engineer - Berkey, APF

B. Detailed requirements for J-75P-19W engine tear-down has been forwarded in December to SAAMA. Instructions call for written report and photograph of findings. A total of five engines has been requested either from F-105 or F-106 aircraft. However, requirements for low time or no time on 7808, giving maximum time on 23699 eliminated F-106 engines from consideration. Initial two engines will be inspected at Wright-Patterson AFB, remaining three shall be inspected at AMA.

Principal Engineer - Posson, SEJ

Associate Engineer - Berkey, APF

C. The Navy will be queried regarding its operational experience with the use of MIL-L-23699 oil.

Principal Engineer - Maloney, SEJ

Associate Engineer - Berkey, APF

4. Various programs have been established to evaluate engine and accessory equipment capabilities with MIL-L-23699 oil.

A. J-75 engine testing is under way to determine low-temperature operating values and/or limits. Both low-temperature starting characteristics as well as bearing lubrication (oil flow data) are being accumulated and evaluated.

Principal Engineer - Miller, SEJ

Associate Engineer - Berkey, APF

B. Low-temperature starting and operation tests of a J-79 engine will be conducted at the APGC climatic hangar to assess operating limitations.

Principal Engineer - Thomas, SEJ

Associate Engineer - Berkey, APF

C. Under the Component Improvement Program, it is planned to evaluate low-temperature starting and operating limitations of the J-85, TF-33, T-56, T-58, T-63, and T-64 engines and various helicopter transmissions.

Principal Engineer - Maloney, SEJ

Associate Engineer - Berkey, APF

D. MIL-L-23699 oil compatibility tests will be conducted on gear boxes, starters, auxiliary power units, constant speed drives, and the F-105 air turbine motor to evaluate operating characteristics and limitations.

Principal Engineer - Miller, SEJ

Associate Engineer - Berkey, APF

5. The equipment industry will be requested to review the operating characteristics of the MIL-L-23699 oil in its equipments. Of particular interest in this program shall be the ability of the equipment to operate over the entire operating temperature range of -65°F to +350°F. Industry shall be requested to review heat rejection rates, possible adverse effects from the removal of lead by oil action, static corrosion of the oil, material compatibility, rotating seal life, and bearing life. Industry shall be asked to provide its experience and recommendations concerning the use and limitations of the oil in view of the foregoing characteristics.

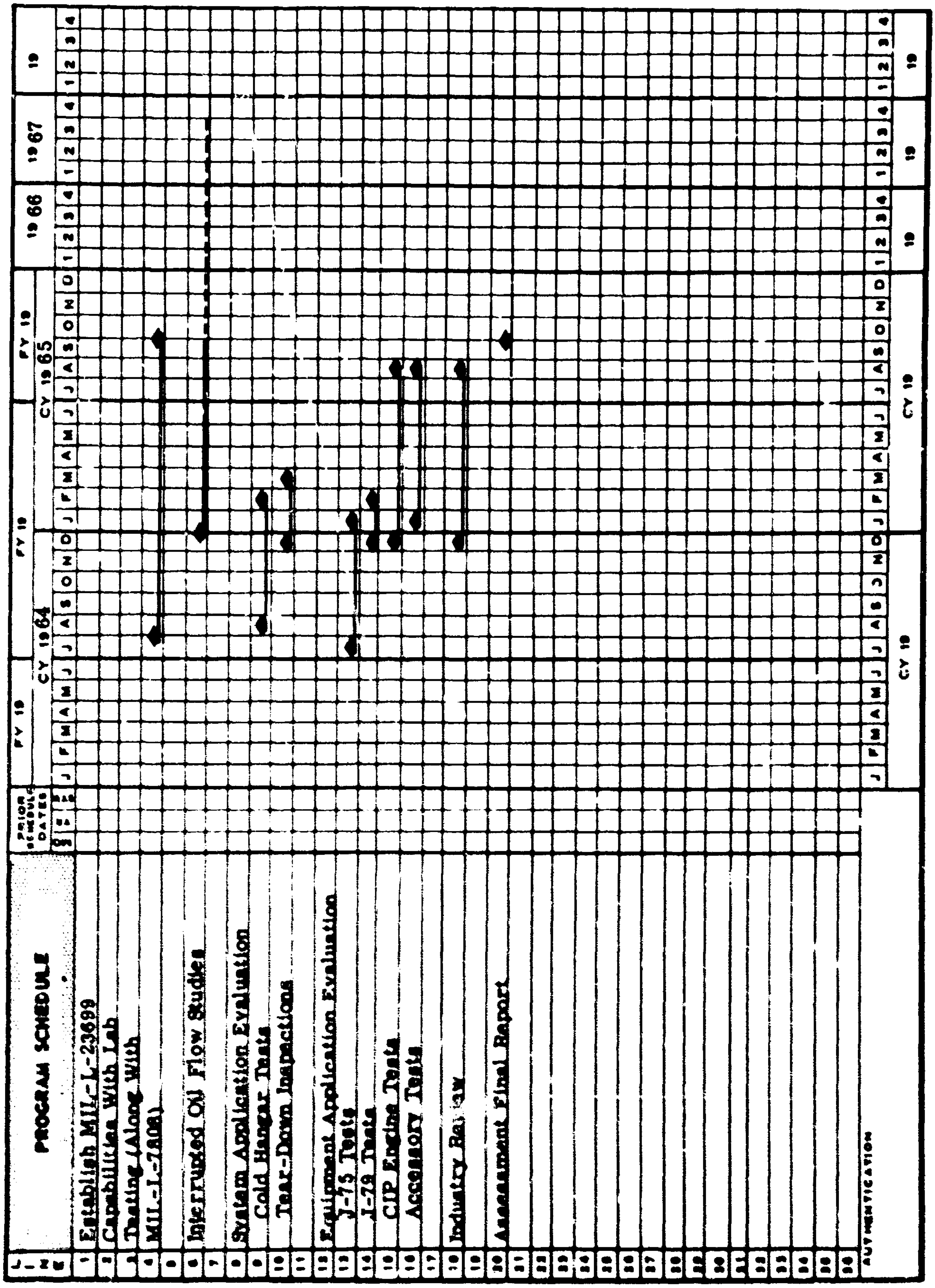
Principal Engineer - Maloney, SEJ

Associate Engineer - Berkey, APF

6. All data obtained from efforts expended under this task shall be reviewed and assessed. A final report documenting the results, conclusions, and recommendations regarding these efforts shall be issued.

Principal Engineers - Berkey, APF

- Farrington, SEJ


PROGRAM SCHEDULE
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CY 1964
CY 1965
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J F M A M J J A S O N D J F M A M J J A S O N D 1 2 3 4 1 2 3 4 1 2 3 4
Establish MIL-L-23699
Capabilities With Lab
Testing (Along With
MIL-L-7808)
Interrupted Oil Flow Studies
System Application Evaluation
Cold Hangar Tests
Tear-Down Inspections
Equipment Application Evaluation
J-75 Tests
J-79 Tests
CIP Engine Tests
Accessory Tests
Industry Review
Assessment Final Report
AUTHENTICATION
CY 19
19

TASK III - DEVELOP NEW OIL

1. Lubrication properties will be established for a new oil based upon known and anticipated equipment usage, field service requirements, and knowledge gained from evaluation of MIL-L-23699 oil and the MIL-L-7808 upgrading program.

Principal Engineers - Berkey, AFP

- Farrington, SEJ

2. Candidate oils will be subjected to extensive tests to determine the acceptability of their physical and chemical properties to fulfill the requirements of an improved oil. The following tests will be conducted:

A. Panel Coker: A General Electric modification of the Model C panel coker to better control air temperature and air availability to the oil has been made. This test which checks coking characteristics of oils will be conducted at panel temperatures of 525, 675, 725, and 775°F.

B. Oxidation - Corrosion: A standard MIL-L-7808 test performed at 347°F oil temperature will also be run at temperatures of 375, 400, and 425°F. This test determines oil oxidative stability and some corrosive properties.

C. ERDCO Bearing Rig: Type I tests (300°F oil and 500°F bearing outer race temperatures) and higher temperature tests (up to 550°F and 600°F bearing outer race temperatures) will be performed. This test measures the lubricity, oxidative stability, and deposit forming characteristics of an oil.

D. Elastomers: MIL-R-25897 (fluorocarbon) and MIL-R-25988 (fluorosilicone) tests will be used to check oil-elastomer compatibility at temperatures up to 400°F and 350°F, respectively.

E. Vapor Phase Coker: The test measures the coking characteristics of oils in the vapor and oil mist phase to predict breather line and sump wall deposition problems. Surface temperatures up to 1000°F will be investigated.

F. Seal Deposition: A new test method recently developed for oils will be performed up to 400°F oil and 1100°F seal air temperatures to determine oil coking and sludging characteristics in the presence of large dynamic seals.

G. Full-Scale Engine Tests: Qualification tests, as defined in MIL-L-7808E, will be conducted at an oil-in temperature of 300°F on a J-57 engine.

H. Selective accessory tests will be performed as considered necessary to assure compatibility.

Principal Engineer - Berkey, APF

Associate Engineer - Wright, SEJ

3. The requirements for the new oil will be specified and released in an exhibit with the simultaneous release of the corresponding specification for coordination.

Principal Engineer - Berkey, APF

Associate Engineer - Farrington, SEJ

4. Oils meeting the requirements of the exhibit will be procured and made available in quantity to major propulsion and power hardware contractors for oil to hardware tests to that extent required to establish hardware compatibility.

Principal Engineer - Wright, SEJ

Associate Engineer - Berkey, APF

5. Depending upon the confidence levels achieved in ground testing, weapon system field service testing will be conducted.

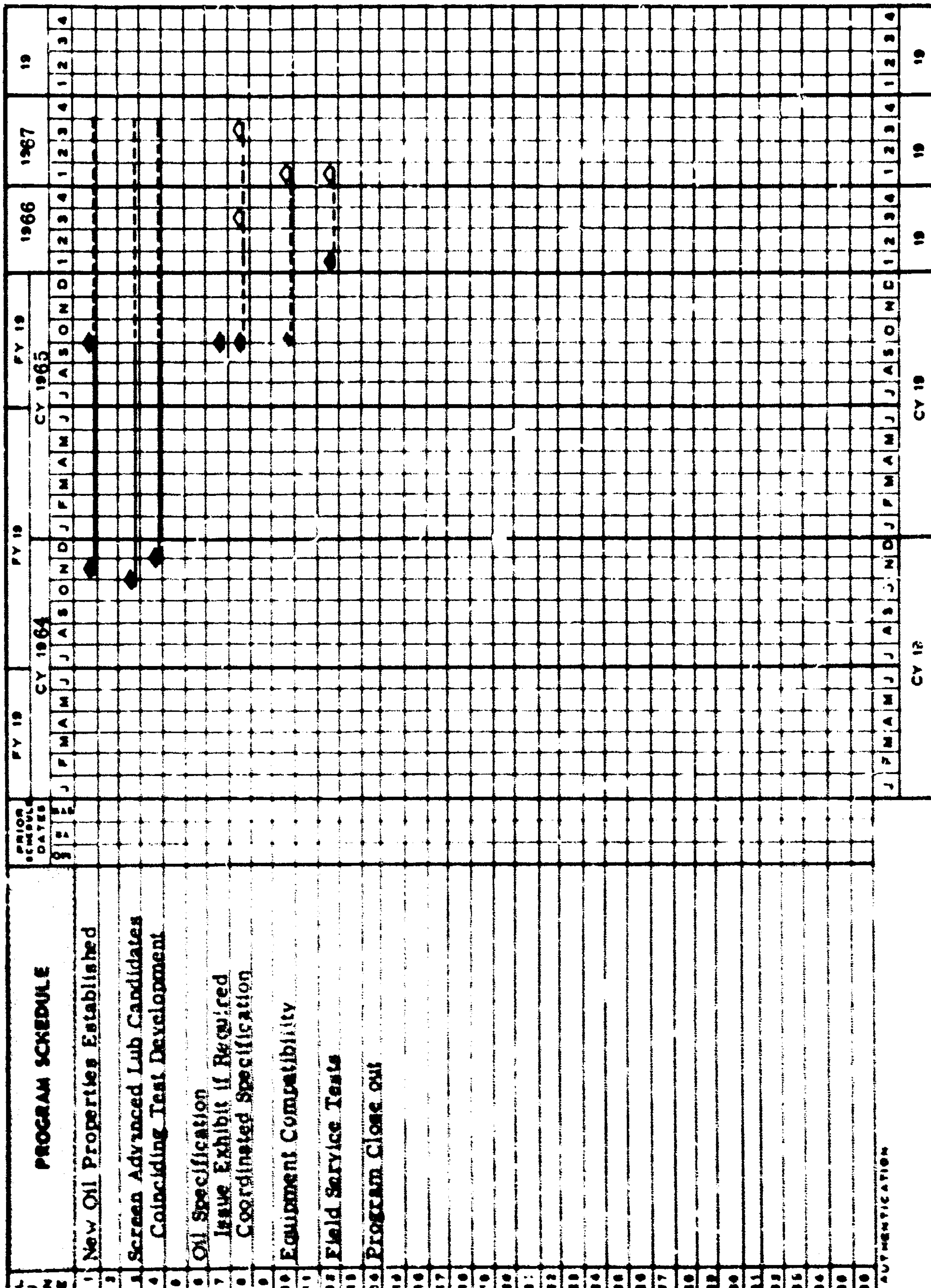
Principal Engineer - Wright, SEJ

Associate Engineer - Berkey, APF

6. Program closeout (oil selection decision) will be based upon all data generated and obtained.

Principal Engineers - Berkey, APF

- Farrington, SEJ


PROGRAM SCHEDULE
New Oil Properties Established
Screen Advanced Lub Candidates
Coinciding Test Development
Oil Specification
Issue Exhibit if Required
Coordinated Specification
Equipment Compatibility
Field Service Tests
Program Close out
AUTHENTICATION
PRIOR SCHEDULE DATES
FY 19
CY 1964
CY 1965
1966
1967
J F M A M J J A S O N D

APPENDIX II

MODIFICATIONS TO THE PANEL COKER

1. INITIAL MODIFICATIONS

An aluminum blank-off plate was positioned around the shaft hole in the sump to more closely control air flow through the sump.

Elevated temperature air was circulated through the sump to decrease the cooling effects on the test oil.

Test panel material was changed from aluminum to 321 stainless steel to permit higher panel test temperatures.

The sump heater capacity was increased from 125 watts to 400 watts to permit higher panel test temperatures.

2. ADDITIONAL MODIFICATIONS RESULTING FROM AFAPL OBSERVATIONS

Large variations in oil level were encountered in the original configuration due to the direct introduction of makeup oil into the sump from the 500 ml reservoir. The modification consisted of adding a small reservoir between the 500 ml reservoir and the sump. The 500-ml reservoir, fitted with a two-tube feeder in place of the original one-tube feeder, rests directly on top of the small reservoir which is, in turn, connected to the sump by a tube. This arrangement feeds oil in much smaller quantities per feed but at more frequent intervals than originally thus maintaining a more constant oil level in the sump.

Wear of the aluminum bushing allowed misalignment of the shaft. The aluminum bushing was replaced by a ball bearing. However, shaft wobble problems were still encountered. A cantilever arrangement was then adopted whereby the shaft is supported only by the drive motor gearbox.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Air Force Aero Propulsion Laboratory Wright-Patterson Air Force Base, Ohio	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

AIR FORCE AERO PROPULSION LABORATORY EFFORTS UNDER THE RTD PLAN FOR IMPROVED AIRCRAFT TURBINE ENGINE LUBRICANTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

September 1964 to October 1965

5. AUTHOR(S) (Last name, first name, initial)

Berkey, Kerry L.; Beane IV, George A.; DeBrohun, Leon J.; et al

6. REPORT DATE January 1967	7a. TOTAL NO. OF PAGES 47	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) AFAPL-TR-66-132	
b. PROJECT NO. 3044		
c. Task No. 304401	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		

10. AVAILABILITY/LIMITATION NOTICES

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Aero Propulsion Laboratory Wright-Patterson Air Force Base, Ohio

13. ABSTRACT

Some Air Force using commands were concerned as to the adequacy of MIL-L-7808E synthetic lubricants for aircraft turbine engines because of deposit forming characteristics. In addition, the U. S. Navy was investigating a class of heavier ester fluids for turbine use. Its requirements for these oils were listed in Specification MIL-L-23699. In agreement with the Air Force Logistics Command, the Research and Technology Division established a fullscale program to improve USAF gas turbine lubricants. The program, "RTD Plan for Improved Aircraft Turbine Lubricants," was conducted jointly by the Systems Engineering Group and the Air Force Aero Propulsion Laboratory. The program was conducted in three phases: investigation of more stringent MIL-L-7808 requirements, assessment of MIL-L-23699 oil capabilities, and investigation of advanced new materials. This report covers only the efforts of the Air Force Aero Propulsion Laboratory in the program.

From the program, MIL-L-7808E was upgraded to MIL-L-007808F (USAF) by tightening existing requirements and adding new deposit forming and elastomer compatibility test requirements. MIL-L-7808 and MIL-L-23699 oils were compared and found to be comparable from a deposit forming standpoint. The decision was made to retain the MIL-L-7808 oils as the standard USAF aircraft turbine lubricant. Efforts were initiated to develop better oils than either the 23699 or existing 7808 oils.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Lubricants						
Oils						
Synthetics						
Aircraft Turbine Engines						
Specification MIL-L-7808						
Specification MIL-L-23699						
Deposit Formàtion						
RTD Panel Coker						
Oxidation - Corrosion						
Bearing Tests						
Elastomers						
Vapor Phase Coker						
Infrared						
Seal Deposition						
Engine Tests						

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